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A COMPARATIVE STUDY OF THE DEVELOPMENT OF SOME ANTHRACNOSES.

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(WITH PLATES VII–XVIII)

INTRODUCTION.

THE investigations recorded in the following paper were undertaken (1) for the purpose of ascertaining by the growth characters developed in artificial cultures, the relationship of certain fungous diseases grouped under the common name of anthracnose, and (2) to determine, if possible, by a study of their life histories, the connection of these so-called imperfect fungi with perfect or ascigerous stages.

Following the established precedent I have included under this general term certain conidial forms belonging to the family Melanconiaceæ; and a few species of the closely related sphæropsidaceous genus Vermicularia, and Volutella belonging to the Tuberculariaceæ, which so closely approach the genus Colletotrichum in their structural characters and in the effect upon the host plant that diseases belonging to these genera have been referred to the anthracnoses,[1] have also been studied.

[1] The popular term anthracnose has no systematic value. The name first applied to the "bird's eye" fungus of the grape (*Sphaceloma ampelinum* De Bary, Bot. Zeit. **32**: 451. 1874) has since been applied to diseases having a similar external appearance and agreeing in general in microbotanical characters.

The greater number of diseases described as anthracnoses have fallen under the genera Glœosporium and Colletotrichum. These are characterized as fungi appearing at the time of fruiting in subcutaneous or subepidermal acervuli, which at maturity become partly erumpent. The conidia are borne upon basidia arising from a more or less definite basal stroma. At maturity the conidia issue upon the surface of the host in a conglutinated mass, usually of a roseate hue. The acervuli frequently occur upon the host in quite regular concentric circles. The characters of the genus Colletotrichum agree in the main with those of Glœosporium, with the exception of the presence of setæ in the former genus, which is not an absolute line of distinction, however, since Glœosporium develops occasional setæ, and the setæ in Colletotrichum sometimes become so reduced in number that the pustules cannot be distinguished from those of Glœosporium.

The large number of species of these genera, which closely resemble each other in structural characters, and the fact that the anthracnose of one host will adapt itself to others, indicate their close relationship, and suggest that many more species have been established than should be maintained. Moreover, species are often established, especially among the imperfect fungi, from characters which vary with the conditions of growth.

It is well known that these fungi, though parasitic, adapt themselves quite readily to saprophytic conditions, and may be grown in various nutrient media. In artificial cultures, distinct species present more or less marked growth characters, and it is with the aid of these characters that I have attempted to relate, or distinguish, the species of some of this group of fungi, since the characters peculiar to each are sufficiently constant and well marked to be of taxonomic value.

In studying the characters, the ordinary dilution culture method has been employed, and the colonies photographed from Petri dishes. The fungus is then transferred to tubes of sterilized nutrient media. Various media have been employed, but sterilized bean stems have proven the most satisfactory for gen-

eral purposes, as they are rich in nitrogenous matter and the fungus has a vigorous healthy growth upon a substratum of a consistency near that upon which they are accustomed to grow.

Of nearly all the species studied, the structural characters and relation to the host have received previous study from an economic standpoint; in such cases these points have been briefly mentioned. While germination of conidia has been observed in all species, a detailed account of those which agree quite closely would be tedious; it has, therefore, been usually omitted except in cases where some differences from the normal type have been observed.

Herbarium specimens, tube cultures, and microscopic mounts have been placed in the Botanical Department of Cornell University where the work has been conducted.

My acknowledgments are due to Professor George F. Atkinson at whose suggestion the work was undertaken and to whose ready advice and assistance I have been greatly indebted, and to Messrs. J. B. Ellis, S. M. Tracy, Byron D. Halsted, and others for their cheerful compliance to requests for fungi from their herbaria.

GLŒOSPORIUM FRUCTIGENUM Berk. (*figs. 1–4, 33–38, 83*).

This species, which has been so fully and carefully described by Miss Southworth,[2] and to which Mr. Alwood[3] has recently devoted considerable attention, is comparatively rare in the northern states. The material from which the disease was studied was obtained from apples in the northern markets and from quinces in an orchard at Ithaca. The presence of the fungus was indicated by the characteristic dark brown spots which spread rapidly in size and become somewhat sunken. The center of the spot becomes quite dark in color from the numerous black pustules which rupture the epidermis a few days after the spot has made its appearance. From some of the pustules the abundance of conidia presents a pale rose

[2] Jour. Myc. **6**: 164–173. 1891.

[3] Ag. Exp. Sta. Virginia, Bull. no. 40, May 1894.

color; at the margin of the spot the pustules are frequently arranged in concentric circles.

Sections of the fruiting bodies show the extreme variation marked by Miss Southworth. The developing stroma at the base of the pustule causes in some a depression in the tissue of the host, which is shrunken and brown for some distance down in the fruit. In others there is scarcely any depression; the base of the pustule is very narrow, and the basidia, which become septate with age and quite dark in color, spread gradually and extend a considerable distance above the host, giving the pustule in cross section a flabellate appearance. In the older pustules the disappearance of the basidia at the center was observed, and in addition to the ordinary conidia, on some of the elongated basidia were borne large oval or club-shaped bodies which become fuliginous, and are single-celled or once septate. They resemble the so-called secondary spores so frequently observed in artificial cultures. The conidia are hyaline, single-celled, elliptical, ovate or sometimes curved, varying considerably in size and shape.

In a dilution culture of meat-, or potato-agar, the conidia germinate readily within three or four hours. A germ tube is developed usually near the end of the conidium, which becomes coarsely granular and the contents begin slowly to pass into the tube. Two or three germ tubes frequently arise from the conidium. Sometimes the conidium upon germination becomes septate, but this is the exception under favorable conditions of growth. The fusion of the conidia mentioned by Mr. Alwood[4] is not peculiar to the species, but is frequently seen in other species, and is apparently due to a lack of nutrition, as it is most noticeable in water cultures or in agar-agar cultures when the growth is crowded, or when the nutritive material is exhausted.

Within two or three days after sowing is made, the small stellate colonies may be seen in the agar with the unaided eye. They are subcircular or elliptical, the center being marked by a slightly elevated, more compact growth of mycelium, elongated

[4] Loc. cit., 67.

and radiating in two to five directions. Upon this growth the first and most abundant development of conidia takes place, which gives it a flesh color; beyond this the growth is nearly uniform. The colony is almost colorless at first, later assuming a delicate flesh color with the pigment developed in connection with production of conidia. The conidia are formed acrogenously on the branches of the mycelium; as the successive ones are formed they push the older ones aside, where they may be seen lying in evenly arranged rows or piled up in little heaps. Becoming more numerously developed in some places, they form light pink acervuli quite evenly distributed over the colony.

On bean stems the fungus develops a dense white or grayish mycelium, which extends over the stems and the surface of the infusion in a flocculent weft. About three days after transferring, blackened fruiting sori make their appearance upon the stems; from these issue the pink masses of conidia, varying in color under different conditions; in parallel cultures the pigment had a deeper tint on infusion of apple than on bean stems. With age there is developed an abundant stroma, spreading over the stems and underlying the younger flocculent mycelium. The mycelium forming the stroma becomes coarse, irregular, and dark colored.

In old plate cultures the protoplasm of the mycelium has been seen to break up into elliptical spore-like bodies arranged somewhat diagonally in the cells or placed end to end. The dark, club-shaped bodies may be lacking in the entire life cycle of this species, but conidia sown in a hanging-drop of water frequently send out a short promycelium upon which these bodies are borne the second or third day after germination.

It has been observed that in old cultures on bean stems, especially in those that have been repeatedly transferred, the acervuli become less prominent, in fact scarcely make their appearance at all; but an abundant stroma is developed. This peculiarity corresponds apparently to the habit of the fungus on its natural host, for in the older pustules, in which the ends of the basidia have grown out in long, dark colored filaments, the

production of conidia seems to have ceased, and the ends of the hyphæ terminate in the enlarged bodies.

The Glœosporium found on the quince produces also a dark brown depressed spot which increases by well-marked concentric rings. The tissue remains quite firm, becoming more or less hardened, and frequently cracks. In the growth characters of the colonies, and in the habit on bean stems, the resemblance to the species found on the apple is so close as to leave no doubt that the two fruits are infested by the same species ; the slightly different effect produced on the host being doubtless accounted for by the firmer tissue of the quince. Professor Halsted[5] further confirmed the identity by inoculating the quince with "virus" obtained from the apple. The writer has also successfully transferred the Glœosporium from the quince to the apple. However, since these forms easily adapt themselves to artificial cultures and are in a measure saprophytic, too much importance should not be attached to the results of laboratory inoculations, where the conditions are more or less artificial.

No indication of a yeast form has been found in connection with the development of the species.

GLŒOSPORIUM PHOMOIDES Sacc. (*figs. 5–7, 39–41*); on tomato (*Lycopersicum esculentum*).

An anthracnose causing a ripe rot of the tomato is manifested at first by a small circular depressed area. Older spots show a lighter central portion surrounded by a dark marginal band 2–3^{cm} in diameter. Upon the central portion, the dark-colored fruiting pustules first appear, producing irregular fissures in the epidermis, which often turns a bright yellow on the margins. From the pustules the conidia ooze out in light pink masses. With age the diseased portions become quite black.

The spore measurements vary considerably from those given in Saccardo (3:618), some of them measuring 18.5×5–6μ. In shape they may be oblong, elliptical, fusoid or reniform, and sometimes curved.

[5] N. J. Ag. Exp. Rept. 316–317.

The acervuli in section bear little resemblance to those of the ripe rot of apple. From a well developed cup-shaped stroma, lying some distance beneath the epidermis, the short continuous basidia arise. They do not project beyond the host, but the conidia are delimited beneath the epidermis. Although the acervuli may be closely adjacent, they seldom become confluent, and the structural characters maintain a greater uniformity than is seen in *G. fructigenum.*

In dilution cultures with meat- or potato-agar, however, the two species resemble each other in the early appearance of the colony. The conidia of *G. phomoides* germinate readily, frequently becoming once septate. The colonies show the dense, elongated, Y-shaped, or stellate center ; the marginal growth does not present the regular, more or less parallel arrangement of hyphæ seen in *G. fructigenum,* although this character depends somewhat on external conditions. With age, however, the roseate tinge of the colony is less marked. The mycelium is nearly or quite white until a stroma begins to develop. This usually makes its first appearance in a circle about midway between the center and the margin, when the colony is from six to nine days old. This extends gradually both toward the center and the margin of the entire colony, frequently becoming in time a dark reddish-brown. In parallel cultures of the two species this difference is more marked in potato- than in meat-agar. In meat-agar the mycelium approaches the buff-pink tinge seen in *G. fructigenum,* but here also a stroma is conspicuously developed. So uniform is this feature that it seems a valuable specific character. On bean stems the mycelium is a grayish-white at first, rather long and spreading ; an abundant stroma is developed subsequently, which discolors the stems with thin, spreading, elliptical patches ; upon these the dark fruiting pustules are situated. While the appearance on the stems is suggestive of the Glœosporium of the apple and quince, in parallel observations of the two, the Glœosporium of the tomato was distinguished by the darker fruiting pustules, and the duller tint of the conidium mass. At different times, however, and under

slightly varying conditions of the infusion of bean stems, these characters were found to vary and were not regarded as of so much importance as the characters developed in Petri dishes. Notwithstanding the fact that this fungus has been found to grow on the apple and quince in laboratory inoculations, the characters manifested in artificial cultures are sufficiently distinct, so that it seems to merit a distinct specific name.

Another disease appearing on maturing tomatoes causes the fruit to crack. These fissures are filled with an abundant white mycelial growth. The conidia are elliptical, oval, or fusoid, and resemble those of *G. phomoides*. On making a dilution culture it was found that the conidia were borne in chains, and proved to be the *Oidium lactis*.

GLŒOSPORIUM VENETUM Speg. (*figs. 8, 42–46*); on *Rubus* sp.

The raspberry is a most generous host for the anthracnoses, and the different genera and species parasitic upon it have formed an interesting group for study.

The most destructive of these, *G. venetum* Speg., has already received considerable attention from economic mycologists, and a brief description of the external characters of this species will suffice. The disease is said to attack all parts of the plant, even the fruit, although so far as the observations of the writer extend, it has been confined to the stems and petioles of both feral and cultivated plants.

It appears first in small purple spots, the oldest ones being found near the base of the plant. As the spots increase in size they become grayish-white at the center, where the tissue of the host frequently becomes ruptured. Encircling the spot may usually be seen an elevated purple border. The disease seldom permeates deeply into the tissue of the plant, but is located chiefly in the cambium layer, where the cells become shrunken and brown.

The conidia form amber colored masses on these spots, and upon examination may be distinguished easily from the other species on the raspberry by their small size. They are oblong-

elliptical, measuring $5-7 \times 2.5-3\mu$. The short basidia, which soon become erumpent, spread over the spot and are not confined to a definite pustule.

The fungus does not adapt itself readily to artificial culture, and considerable difficulty was experienced before obtaining a pure culture. The conidia are not easily distinguished from isolated yeast cells, and a fungus forming light colored masses on the anthracnosed spots, and producing conidia closely resembling the conidia of *G. venetum*, proved to be a yeast form.

The conidia germinate readily in water or agar, but after the germ tube has attained a length of three or four times the length of the conidium, further development is very slow. In agar, numerous short branches are sent out from the primary germ tubes, which become closely septate; the cells, including the conidium, become somewhat swollen, so that the conidium itself can be distinguished with difficulty from the cells of the mycelium. Separation is more or less difficult, since growth in acidified agar is even less favorable than in a neutral medium, and bacterial and other foreign growth is liable to contaminate the cultures before the colonies can be seen in order to be separated.

Many unsuccessful attempts were made to obtain a pure culture of the anthracnose of the raspberry.

As late as November 29 fresh conidia were again obtained. With some of these a culture was made in a hanging-drop of water; dilution cultures were also made in acidified and neutral agar. On the following day the cultures were examined and many conidia were found to be sending out slender germ tubes by which, in the crowded condition in the hanging-drop, the conidia were frequently fused; the tubes attaining three or four times the length of the conidium. Four days after sowing, the germ tubes in the Petri dish cultures had attained a length of $24-60\mu$. They were divided into cells but slightly longer than broad, which were swollen so that the mycelium presented a moniliform appearance. On December 2 transfers of blocks of agar containing germinating conidia were made to tubes of bean stems. The growth at first seemed very unpromising. Small

tufts of white mycelium appeared on some of the stems. By December 22 the growth had spread so as to form colonies about 2–3^{mm} in diameter. Very little mycelium could be seen, but one pink mass of conidia was borne on the upper portion of one of the stems. On examination the mass was found to be composed of closely packed basidia, bearing at the end elliptical or oval conidia 6–7μ in length, although occasionally one was found measuring 12 or 14μ. These were sometimes united by short germ tubes. Dilution cultures were made in potato-agar from this colony. Growth took place very slowly; some of the conidia gave rise to two or three germ tubes, these branched frequently and became closely septate. The resulting colonies did not advance beyond a diameter of 3–4^{mm}. At first they presented a stellate, or snowflake appearance, but later became quite dense and compact, with a close even marginal growth. The mycelium assumed a deep red color, darker at the center and shaded to a light pink toward the margin, and presented a glazed, shining appearance. The production of conidia was not observed. Subsequent transfers to tube cultures on bean stems, as well as on sterilized raspberry stems, resulted in a very slight mycelial growth in scattered tufts. Some of these tufts floated freely on the surface of the infusion, in small stellate colonies, and often became attached to the sides of the tubes. In connection with the mycelial growth were small, pink, elevated masses.

So peculiar was the growth and unlike that of any other species of anthracnose studied, that in order to satisfy myself that the growth was that of the anthracnose, fresh material was again obtained the following July. The growth in agar and on bean stems manifested the same peculiarities as before, but upon closer examination of the newly formed patches on the stems the conidia were found. These quickly fall away and form the small colonies which were before mentioned floating freely on the infusion. The colonies in agar did not attain a diameter of more than 3–4^{mm} when six or nine days old. They presented the same dark red or copper colored center with a compact

chocolate colored or dull pink margin. Upon teasing out the colonies and examining them under the microscope, the conidia were found in all stages of germination. Some of them presented a dumb-bell appearance, while in others the germ tube about equaled the conidium in diameter, so that it could scarcely be distinguished from the vegetating mycelium. This crowded growth, and the rapid germination of the conidia in the colony, probably accounts for the small size attained by the colonies and their dense, hard, interwoven character.

On sectioning portions of the bean stems upon which the fungus was growing, within the tufts of mycelium were found perithecia-like bodies with delicate walls of closely interwoven mycelium. These were quite small, measuring from 60 to 70μ in diameter, ovate or pyriform. The peripheral cells were light brown, the interior was filled with light colored cells rich in protoplasm. While this condition suggests an ascigerous stage in connection with the fungus, it has not yet matured.

On the hyphæ surrounding these bodies were developed buds or gemmae; these were smaller than those found in other species but were of the same general shape, and of a dark brown color.

SYNONYMY.—*Glœosporium venetum* Speg. is commonly regarded as a synonym of *G. necator* E. & E., the original distinction being that the former one affected the leaves while the latter was confined to the stems. This distinction is now seldom regarded, the description of the two as found in a natural state agreeing so closely that there is little doubt as to their identity. Not having obtained cultures from the fungus on the leaves, the writer is unable to discuss their growth characters in nutrient media.

Glœosporium naviculisporum, n. sp. (*figs. 11, 58–61*).

While attempting to obtain a culture of *G. venetum*, a species of Glœosporium was found on twigs obtained from Mr. Pearson, of Vineland, N. J. This proved to be quite a different species, although the conidia were obtained from canes quite badly affected with the characteristic spots caused by *G. venetum.*

The conidia of this new species are larger than those of *G. venetum*, measuring $12–15 \times 4–6\mu$, in shape fusoid or navicular and sometimes curved.

Unlike *G. venetum* the fungus is a rapid grower, the colonies attaining, under favorable conditions, a diameter of 1^{mm} in three or four days. The colonies have a uniform growth of pure white, erect mycelium, resembling at first those of *G. fructigenum*. It is separated from this species, as well as from *G. phomoides*, by the navicular character of the conidia and by later growth characters. In addition to the characteristic development of mycelium, there are developed abundant bright pink acervuli, formed in concentric rings. It is also distinguished in its development on bean stems by the entire absence of stroma; this character was noted throughout many generations of cultures. The abundant mycelial growth noted in the agar-agar cultures was not so marked on bean stems, but large pink acervuli are freely developed and the conidia frequently sink to the bottom of the tube, where they form a thick, pink sediment.

The colored, club-shaped bodies have been noted in hanging-drop water cultures. Growth on bean stems was at first less vigorous than on sterilized raspberry stems, but in laboratory culture it gradually adapted itself to the former. Inoculations were made on cuttings of raspberry stems transplanted in the greenhouse from the garden, in order to ascertain whether the fungus would adapt itself to growth on living stems. Eighteen days after the inoculations were made the fungus reappeared on the stems, the withered petioles, and along the veins of the leaves. As it has since been found on stems obtained from the university gardens in connection with *G. venetum*, it would be unsafe to say that the appearance was due to the inoculation, since the mycelium might have been lurking in the tissue before the transplantings were made, although the canes were in an apparently healthy condition.

The fungus seems to be a different species from those that have been described, and presents also growth characters distinct from the species studied in artificial cultures derived from

different hosts. Unlike *G. venetum* the acervuli are not confined to spots on the host, but spread indefinitely over the stem or leaves. From the form of the conidia I propose the name *Glœosporium naviculisporum*, with the following diagnosis:

Acervuli erumpent-superficial, 60–240μ in diameter, not confined to definite areas on the host. Basidia elevated, hyaline, 30–35μ in length. Conidia fusoid-elliptical, straight or slightly curved; ends acute, hyaline, continuous, measuring $12–15 \times 6\mu$; oozing out in deep pink masses on stems and leaves of Rubus.

HAINESIA RUBI (West) Sacc.[6] (*figs. 10, 51, 52*); on *Rubus.*

Another fungus of the raspberry is described by Saccardo under the name *Hainesia rubi* (West) Sacc. (Syll. **3**:699). This species has been collected in various localities about Cornell University. It is found abundantly on the leaves of Rubus, and is associated with *Cæoma nitens* (æcidial stage of *Puccinia Peckiana*), although this fungus does not seem essential to its existence, since it will grow on artificial media in pure culture. The acervuli are subcuticular, soon subsuperficial, on both upper and lower sides of the leaf. At maturity the conidia ooze out in pale pink heaps.

In section the pustule has much the same appearance as that of *G. naviculisporum*, but the conidia have not the pronounced navicular form found in that species. The colonies have a growth strikingly similar however to that species. There is the same abundant growth of white mycelium which gives the colonies a uniform undifferentiated appearance. The species is fur-

[6] The species which Miss Stoneman has studied here is identical with that described by Ellis and Everhart as *Glœosporium rubi* (Jour. Mycol. **4**: 52. 1888) associated with *Cæoma nitens* on Rubus from Mississippi. There has been no opportunity to compare this material with the European specimens, but since their habitat is identical (association with Uredineæ on Rubus), the difference in measurement of the spores, which is not very great, would not seem a sufficient ground for the separation of the species, if they are generically the same. The genus Hainesia has forked and branched basidia. This character is certainly not common in the American specimens which I have examined. While there is a strong probability that the American and European specimens are the same species, it is not possible at present to speak with certainty.—G. F. A.

ther distinguished from *G. naviculisporum* by the development of a stroma in old cultures on sterilized bean stems.

Glœosporium cactorum, n. sp. (*fig. 14*); on *Cactus* sp.

There is a member of the genus Glœosporium which infests the cactus in greenhouse cultivation. The acervuli are erumpent-superficial, pale pink, becoming dark colored, situated on dark brown, decayed spots. On the margin of the spots the acervuli become confluent, often forming a close ring surrounding the less gregarious acervuli of the central portion. The conidia are elliptical, with rounded ends, and measure 12–17 $\times$ 4–6μ.

The conidia germinate readily in nutrient agar, and growth takes place rapidly. The colony has a white, snowflake appearance, belonging to a group showing a loose, open growth at the center, with the slender radiating strands of mycelium growing from the central point. The growth of the mycelium above the surface of the agar gives the colony a downy or flocculent appearance. The marginal mycelium presents a less regular growth than is seen in the open centered colony of *Colletotrichum glœosporoides*, and the open center is usually less distinct. By comparing the colonies with those of *G. cingulatum* Atk. (see *fig. 26*) a close resemblance will be observed. The latter, however, differs in the looser, irregular marginal growth, as well as in morphological characters, which will be discussed more at length in connection with that species.

On bean stems a dense growth of white mycelium is produced, which shows later a slight development of stroma appearing along the edges of the stems. A well developed stroma is formed at the base of the acervulum. The conidia ooze out in light pink masses. Associated with the acervuli are compact stromata, forming dark spherical elevations on the stems. Their appearance suggests perithecia, but no indication of asci has been found in connection with the species. *Fig. 17* represents colonies of the same species collected from a different variety of cactus a year later.

GLŒOSPORIUM MUSARUM Cke. & Mass. (*fig. 11*), on banana (*Musa paradisiaca*).

The anthracnose of bananas is quite commonly found on ripe bunches of the fruit in warm weather. The fungus appears in roseate, innate, erumpent, gregarious acervuli on blackened spots of the fruit. These spots spread over the entire fruit, and the underlying tissue becomes disorganized. The conidia are elongate, ellipsoidal, rounded at each end, usually with a single vacuole, and measure $16–18 \times 4\ \mu$.[7]

The material from which the first cultures were made was obtained from Ellis & Everhart's N. A. F. no. 3178. Conidia from the material collected in July 1894 germinated readily when sown in November of the same year. Germination takes place in the ordinary manner, one or two germ tubes originating at or near the end of the conidium. The conidia remain single-celled upon germination. Growth is rapid and the first crop of conidia in potato-agar appears the second day after sowing. The colonies have at first a stellate appearance, which becomes more or less obscured with further growth. Hyphal growth is sparse at the center, and the mycelium radiates in more or less straight lines. The flocculent or feathery radiations extending from the center to the margin give the colony a characteristic appearance. It is at first grayish in color, and assumes a buff tinge when the acervuli appear, which are scattered irregularly over the surface. Very little mycelium is developed on bean stems, but a compact grayish mat spreads over the surface of the infusion. Over this mat, as well as on the bean stems, the acervuli are produced in great abundance. They are comparatively large and attended with the development of a stroma, which does not spread thickly over the stems as in *G. cactorum*, *fructigenum*, and *phomoides*. Its entire growth marks it as a species distinct from the others that have been studied. The fungus readily adapts itself to various nutrient media. Although growing upon soft tissue on its natural host it shows a vigorous growth

[7] The original description in Grevillea (16:3), gives the spore measurements $12 \times 4\mu$.

of mycelium and an abundance of acervuli when transferred to sterilized oak and grape stems. The development of the so-called secondary spores has not been observed in cultures of this species.

Glœosporium fœtidophilum, n. sp.[8] (*fig. 12*); on skunk cabbage (*Spathyema fœtida*).

The Glœosporium which was found to infest this host causes black depressed, elliptical spots on the spathes. In a microscopic section, the cell walls are found to be very much collapsed; with the exception of those cells just above the acervuli, which frequently retain their normal shape and color though elevated by the underlying mycelium, and causing pale elevated spots on the surrounding blackened portion. The acervuli remain covered for some time, and the customary basal stroma is lacking; the mycelium forms an irregular, loosely interwoven mass at the fruiting points, the conidia being borne some distance beneath the surface, frequently filling the large intercellular spaces. They are slender, elliptical, and slightly inequilateral, varying in size from $7–12–15 \times 2–3\mu$.

Conidia sown in a hanging-drop of water become closely granular or vacuolate, usually once septate and frequently swollen at the ends, previous to germination. They send out two or three germ tubes which produce conidia quite close to the mother conidium. In potato-agar the growth is much more vigorous, as many as five germ tubes having been observed to originate from a single conidium. These branch frequently in a monopodial fashion and the conidia are abjointed so abundantly as to give the colony a yeast-like appearance. The colony is characterized by the pronounced stellate radiations which remain quite distinct from each other in the earlier growth, but the outspreading mycelium becomes more or less intermingled, rendering the radiations less pronounced. About 2^{mm} from the center these radiations branch profusely, giving to the colony a more or less uniform margin. The colony which is at first quite white assumes with age a pale yellow tinge.

[8] Collected by Professor G. F. Atkinson, Ithaca Flats, April 10, 1896.

On bean stems there is scarcely any development of mycelium. The conidia do not remain collected in heaps, but spread over the stems or collect in a dense layer on the surface of the infusion. The cultures in the tubes are also characterized by the uniform yellow tinge. No stroma develops in the cultures, and the colored club-shaped bodies are not formed either in agar, in bean stems, or in a hanging-drop.

The characters are as follows: acervuli for a long time covered, finally erumpent, situated on black depressed spots. Basidia short; conidia sometimes borne on intercellular hyphæ, hyaline, elliptical, ends acute, $7–12–15 \times 2–3\mu$. On spathes of *Spathyema fœtida.*

GLŒOSPORIUM NERVISEQUUM (Fckl.) Sacc. (*figs. 13, 53–61*); on oak (*Quercus*), sycamore (*Platanus*).

This species may be easily recognized on the host by the shrunken withered veins of the leaves bordered by arid brown patches. The fungus causes the leaves to curl and become much distorted in appearance. The conidia, which may be found from early in June until November, are distinguished from the usual type of Glœosporium by their ovate pyriform contour, some being so constricted at one end as to appear almost stipitate. Others are more regular in shape, ovate-oblong or oblong, measuring $10–12 \times 4.5–5\mu$.

Owing to the slow growth after germination has taken place, considerable difficulty was experienced in obtaining a separation culture, as it was closely associated upon the leaves with cladosporium, a pycnidial form, and other rapidly growing fungi.

In several unsuccessful attempts to obtain a culture from affected oak leaves, a peculiarity in germination was observed; the germ tube, which had a bulbous swelling at the base, made a short curve near its origin, sometimes encircling the conidium in a close coil. After germination had been observed the pieces of agar containing the germinating conidia were transferred to infusions of oak leaves. No satisfactory growth, however,

resulted from these cultures, which were made early in October, and they were discarded. On October 28 a Glœosporium was found on the leaves of a sycamore on Ithaca Flats. The veins of the leaves had the withered appearance and were bordered by the irregular patches which characterized the disease on the oak. Upon the under side of the leaf brown acervuli were produced, on which an abundance of conidia were found. The acervuli were not confined so closely to the region bordering the veins as was the case on oak leaves, and the withered portions were more expanded, but the color of the pustules, and the spore measurements were the same, and the same peculiarity in germination was noted, the germ tube frequently coiling once and a half or twice around the conidium. The fungus was less contaminated on the sycamore, and the growth could be more satisfactorily observed. On the day following the sowing of the conidia many were found to be germinating, sending out one or two germ tubes. On the third day after germination from three to five tubes could be seen to issue from a conidium which had in some cases become once septate, and the cells were slightly swollen.

The colonies in nutrient agar produce a rather scant mycelial growth, the clusters of conidia forming grayish masses for the most part submerged in the agar, are borne quite uniformly over nearly the entire colony. The colony has a loose, feathery, almost uniform growth, there being no marked radiations or abundant central growth. In both meat- and potato-agar the growth is slow. On bean stems, also, there is a very slight, inconspicuous growth of mycelium, and the tube cultures are marked by the pale brown acervuli which are produced quite freely on the stems.

In the following June (1896), material was again studied from diseased oak leaves; the appearance on the leaf and in section, as well as the peculiarity of germination and the growth developments in Petri dishes and test tubes, are sufficient evidence that the same species of Glœosporium infests both sycamore and oak.

COLLETOTRICHUM GLŒOSPORIOIDES Penz. (*figs. 15, 84*); on orange (*Citrus aurantium* L).

This disease, which was found on an orange tree in the conservatories, is also said to infest plants in outdoor cultivation. It causes, at first, light green spots on the leaves, which become collapsed and brown. Upon them are situated the black fruiting pustules which occur on both the upper and under surfaces of the leaf. Some spots show the acervuli arranged in quite regular circles around the margin, surrounding more indefinitely located acervuli at the center. The acervuli increase rapidly when the leaves are placed in a moist chamber, and the conidia ooze out in bright pink masses. They are rather broadly oval, $12–16 \times 5–6\mu$, with one or two large oil drops. In section the acervuli, from $120–270\mu$ in diameter, are seen to be erumpent, superficial, possessing a well-developed basal stroma, which gives rise to short basidia. The setæ, when present, are marginal, flexuous, once or twice septate, attaining a length of 130μ.

On bean stems the fungus develops an abundant loose, white, flocculent mycelium. The conidia ooze out in large masses, of a deep pink or orange color; a blackened stroma is developed quite abundantly, and the growth resembled that of *G. fructigenum*, of which parallel cultures were studied. Subsequent cultures, however, developed quite different characters in the colony than those of that species. The compact center developed in *G. fructigenum* is not seen in *Col. glœosporioides*. From the small central point of the colony of the latter species the mycelium radiates in from two to five directions. The branching of the mycelium is more or less suppressed at the center until the mycelium attains a growth some distance from the center. It there branches abundantly, the branches spreading out in a fan-shaped growth. These marginal tufts for a time remain quite distinct, but in older colonies well supplied with nutriment they mingle more or less, forming a continuous circular margin. The clear spaces at the center usually remain. The fruiting clusters appear in a circle some distance from the center. More or less of a stroma is developed in connection with the acervuli, so that

they appear as black points in the white mycelium. At times there is a pink pigment developed, which gives color to the acervuli. In subsequent transfers to bean stems, in which the mycelium was less abundantly developed, the pustules showed a considerable formation of stroma, and setæ were distinctly seen, although their presence is quite variable.

COLLETOTRICHUM LAGENARIUM (Pass.). Sacc. and Roumg. (*figs. 17, 18, 62–69, 75–79*); on watermelon (*Citrullus vulgaris*).

In Farlow's host index this species is recorded for the following cucurbits; watermelon (*Citrullus vulgaris*), muskmelon (*Cucumis melo*), cucumber (*Cucumis sativus*), pumpkin (*Cucurbita pepo*), and squash (*Cucurbita* sp.).

Its presence is indicated by subcircular brown spots on the rind of the watermelon; on some spots the tissue at the margin may become black, or the order may be reversed and a dark center may be surrounded by a lighter brown portion. Dull roseate acervuli rupture the epidermis, and are arranged more or less concentrically. The presence of setæ is a variable character; in some pustules which were quite mature none could be detected even in carefully prepared microscopic sections. This has led to some confusion in the history of the fungus as to its generic position. The conidia are rather long, narrowly elliptical, 16–20 × 4–5μ, sometimes ovate-oblong or inequilateral.

A section through the pustule shows but a slight development of basal stroma; the basidia are rather long, immersed, but extending partially above the surface of the host.

The fungus does not adapt itself readily to artificial cultures, and several unsuccessful attempts were made before satisfactory results were obtained. Conidia sown in meat-agar were seen to germinate, but subsequent growth took place slowly, and the contents showed disintegration. The mycelium became coarsely granular, and the contents showed disintegration. More satisfactory results were obtained in potato-agar, but here, also, the growth, as well as on bean stems, made but little progress at

first. With successive generations, obtained by making transfers of cultures, the fungus became gradually adapted to artificial conditions, and vigorous growth was obtained in potato-agar.

A normal type of germination takes place; one or two germ tubes arise from near the ends of the conidium, making their first appearance within six or twelve hours after the sowing is made. Twenty-four hours after sowing the conidia have usually all germinated.

The contents of the conidium become coarsely granular, and a clear space at the point of origin of the germ tube is seen as its contents pass into the tubes. The mycelium becomes coarsely granular or vacuolate, and branches in an irregular monopodial fashion. As the colonies exhaust the nutrient medium large hyaline vesicles appear as offshoots of the mycelium, or short branches of the mycelium become very much enlarged at the tips. The colonies make their first macroscopic appearance as small, irregularly stellate bodies; as they become older, the mycelial growth is nearly uniform, radiating from a small, dense central point. The conidia are first formed most abundantly at the center of the colony, where a pink acervulus appears. When the colony attains the age of five or seven days, the acervuli are formed irregularly over the central portion of the colony, the marginal mycelium keeping some distance in advance of the fruiting portion. The setæ are produced quite abundantly on the acervuli; in fact, the characters of Colletotrichum are often more distinctly manifested in artificial cultures than in a natural state. At the center of the colony a compact, reddish-brown stroma is formed, which does not spread far over the colony; beyond this stroma the colony acquires uniformly a buff or salmon tint. Faint concentric markings are sometimes seen in the colony.

Transfers to bean stems give rise at the point of inoculation to a spreading, grayish mycelium which covers the stems and the infusion. About three days after sowing the pustules appear in circular, elevated masses of a dull pink hue. As the culture becomes older they become surrounded by a stroma which gives

them a blackened appearance at the margin, and long setæ project some distance above the mass of conidia; these are dark brown except at the base, which is nearly hyaline, and they are frequently once or twice septate. The stems become blackened with a coarse, dark stroma, of irregular, more or less swollen cells, often terminating in club-shaped bodies. The mycelium does not develop below the surface of the infusion, but forms a compact coating over the surface which becomes glazed and shining, and of an intensely dark, reddish-brown color, becoming almost black, retaining, however, a reddish, iridescent hue.

The Colletotrichum on cucumber agrees so closely in all the growth characters that parallel cultures of the two in agar or on bean stems cannot be distinguished from each other. The similarity of growth leaves no doubt as to the identity of the species found on the two hosts, although the illustration of the two in section, and the appearance which the fungus gives to the host, might lead one to suppose them distinct species.

COLLETOTRICHUM LINDEMUTHIANUM (Sacc. & Magn.) Scribner, 1887 (*figs. 19–20, 70–74*); on bean (*Phaseolus vulgaris*).

The history of the anthracnose of the bean has been an interesting one, and much discussion has arisen in regard to its position and nomenclature.

We have an account of its first observation by Lindemuth at Popplesdorf, 1875. It was described and named in his honor by Saccardo and Magnus in *Michelia* 1 : 129, under the name *Glœosporium lindemuthianum*. Owing to its economic importance it subsequently received considerable attention, and has been figured and described in various journals.

Professor Scribner (Rept. Veg. Path. 1887), records the presence of setæ in the acervuli, and suggests that the species be placed in the genus Colletotrichum. In the report of the United States Department of Agriculture, 1887, Mr. Galloway describes the fungus and mentions that the presence of setæ was constant, though very scarce in some cases, in all the material. He also

suggests that the species be transferred to the genus Colletotrichum or Vermicularia.

Under the title "Identity of anthracnose of the bean and watermelon,"[9] Dr. Halsted describes some interesting experiments in inoculation of anthracnoses. The anthracnose of the watermelon was easily transferred to the bean, and a third fruit, the citron, was made to receive the anthracnose of both bean and watermelon; and he therefore regards the anthracnose of bean and watermelon, as well as that of the cucumber and muskmelon, as identical. So different was the development of the watermelon anthracnose from that described by Professor Atkinson[10] for the anthracnose of the bean (*Colletotrichum lindemuthianum*), that the latter was compared in artificial cultures with *G. lagenarium*.

Some rusted beans of the Wardwell kidney wax variety were obtained and placed in a moist chamber to germinate. After the first pair of leaves had appeared on the stems of some of the seedlings, the anthracnose was manifested in the characteristic depressed patches. The center of the spots was of a light brown color, bordered by a reddish-brown margin. Scattered over the depressed portions were the small leather-colored pustules. The appearance on the host marked a difference in the species, the watermelon showing a more indefinitely spreading discolored portion of the host which is not depressed. The character of the pustules in section would give less evidence as to their identity; in fact, there is a similarity both in shape and position of the acervulus, as well as in the length of the basidia and character of the conidia.

Dilution cultures were made in acidified and unacidified agar. The former medium was unfavorable to growth, as none of the conidia germinated. Those in the neutral medium two days later showed signs of germination, while four days after sowing several were found in different stages of germination. The first evidence of activity was seen in the swollen condition of the

[9] N. J. Agr. Exp. Sta. Rep., pp. 347, 352. 1893.

[10] BOT. GAZ. 20: 305–311. 1895.

conidium at either end, which gives it the appearance of being constricted at the center. This agreed with the peculiarity observed by Professor Atkinson, as did the further development of the colony and the appearance on bean stems.

In order to compare the development of the anthracnose of the watermelon and the bean, parallel dilution cultures were made of the two on March 15, in order that uniform conditions of growth might be obtained. The material from which the cultures were made was obtained from separation cultures of the two previously made on bean stems. On March 16 the conidia of *Col. lagenarium* had sent out germ tubes about ten times their length, while others were not so far advanced, being shorter than the conidium itself. Some of the conidia were provided with septa, one usually at the middle. A few of the conidia of *Col. lindemuthianum* showed short germ tubes, but many had only increased in size. Four days later the conidia, which had just begun to germinate, showed the characteristic dumb-bell swelling, and many of those which had germinated earlier were also seen to be considerably swollen, and many were once septate. From some of the conidia as many as four germ tubes had formed. A few which had produced germ tubes of considerable size showed no appreciable difference in size or shape; whether a change would come later could not be determined as they were obscured by the mycelial growth. While the spores of *Col. lagenarium* occasionally become distended, the pronounced dumb-bell appearance is not a feature of germination. The germination of *Col. lindemuthianum* resembles that frequently observed in spores of Marsonia, which are originally septate. As the colonies had exhausted the nutrient medium, the enlarged vescicles observed in the mycelium of *G. lagenarium* were seen in *G. lindemuthianum.* These were larger than those previously mentioned; they were frequently once septate, and sometimes sent out one or several short tubes.

Not only do these two species show distinct differences in early growth, but the mature colonies present a very different aspect. Instead of the salmon cast of the colony, it is at first

a pure white, with a later development of sepia colored stroma over the central portion, where the fruiting pustules are most abundantly developed. This portion of the colony is not confined to such a limited area as it is in colonies of *Col. lagenarium ;* nor does the outer portion of the colony become tinged, but remains a distinct white.

On bean stems the stroma is also soon developed, causing a blackened appearance of the stems, upon which there is but slight mycelial development, but it forms a white mat over the surface, which for some time forms a marked contrast to the blackened stems. In cultures a month old this also develops a stroma.

Since making the original parallel cultures the two species have been subsequently studied in connection with others; and, from material collected at different times and localities, with uniform results. The colonies of the bean anthracnose leave the impression of a study in black and white, while that of the watermelon, one in pink or salmon and a dark reddish-brown. A comparison of the two is well shown in *figs. 17, 18, 19, 20.*

These various differences which are so marked, and which are quite constant under varying conditions of temperature, seem to show conclusively, notwithstanding previous results in inoculation, that the two are distinct species.

From experiments made by the writer, it would seem that very little dependence can be placed upon the results obtained from cross inoculations made in the laboratory. The host to be inoculated is placed in a moist chamber or under a bell jar, where the moisture of the fruit is conserved, and the conditions are then favorable for any fungus which is already lurking in the tissue to develop. On the other hand, it has been shown that the fungi of this group easily adapt themselves as saprophytes, and a watery fruit like the watermelon or citron, which has been separated from the plant, has lost to a degree the power of resistance, and becomes more or less of the nature of a culture medium.

Volutella citrulli, n. sp. (*figs. 24–25, 80–82*); an anthracnose of the citron.

From the Ithaca markets an anthracnosed citron was obtained. It was marked by light brown, subcircular, confluent patches thickly covered with black acervuli, from which the conidia oozed forth in light pink masses. In some of the sporodochia setæ were present, while in others they were wanting. The conidia are hyaline, single-celled, elliptical or clavate, sometimes slightly curved, $15–20 \times 3–4\mu$. From the general macroscopic characters, and the shape and size of the conidia, as well as from the nature of the host, the fungus was at first referred to *Colletotrichum lagenarium* (Pass.) E. & H. Further study, however, revealed quite a marked difference in the two species.

The pustule of the citron anthracnose has its inception in a dense stroma just beneath the epidermis, but it extends some distance above the surface of the host. In some cases the stroma extends up around the basidia, almost forming a covering as is found in the genus Vermicularia. Long basidia arise above the stroma; the elevated basidia and the marginal setæ, when setæ are present, would show a close relationship to the genus Volutella. The setæ are colored, two to three times septate, with a swollen base.

This species develops quite differently from that of the bean, or watermelon anthracnose in artificial cultures. In colonies the salmon colored pigment of *Col. lagenarium* is wanting, and the fruiting pustules are not so centrally located, but appear as light colored pustules more or less separated from each other and somewhat concentrically disposed. A stroma, instead of being centrally located as in the two previously under consideration, appears in clusters of peculiarly contorted sclerotoid bodies terminating in club-shaped cells. These masses are formed in concentric rings, intermingled with the fruiting portions. The mycelial growth radiates in quite straight rays from the center to the margin. The growth on bean stems also presents a different aspect from *Col. lagenarium*, just mentioned.

On the stems the mycelium is scarcely apparent, but with a hand lens it may be seen to form a very sparse growth of short threads spreading out on the inner surface of the tube. The stems bear blackened elevations which resemble perithecia in shape, but which have never been found to be associated with conidia. The conidia do not form large pustules on the stem, but can barely be distinguished as small light colored elevations. The surface of the infusion becomes coated with a light colored scanty growth of mycelium. Within this growth appear light colored elevations composed of aggregations of swollen cells which develop dark membranous enveloping walls, similar in appearance to the dark elevations on the stems.

While it is possible that the species *Colletotrichum lagenarium* infests the citron, the species in question is distinct from the one studied on the watermelon. There seems to be no species described in the genus Volutella which agrees with the one under discussion, and the name *Volutella citrulli* is proposed with the following description:

Acervuli elevated; basidia elongated, seated upon an abundant stroma rising above the tissue of the host. Conidia hyaline, single-celled, elliptical or clavate, sometimes slightly curved, $15\text{–}20 \times 3\text{–}4\mu$. Setæ, when present, marginal, septate, with a swollen base. Forming light brown, subcircular, confluent patches on the rinds of citron (*Citrullus vulgaris*, var.).

COLLETOTRICHUM LYCOPERSICI Chester (*fig. 21*).

Another anthracnose of the tomato is described by Chester[11] as follows: "Spots depressed, circular, slightly discolored, center black, $5\text{–}10^{mm}$ in diameter, becoming confluent. Acervuli abundant, densely gregarious, rusty brown or black, applanate, $95\text{–}150\mu$ in diameter. Setæ abundant, fuliginous, generally curved, rarely undulate or straight, gradually tapering, septate, $65\text{–}110\mu$, about 5μ at the base. Conidia oblong $16\text{–}22 \times 4\mu$, averaging $18\text{–}20 \times 4\mu$, hyaline, 2–3 guttulate. Basidia short, slender, $30\text{–}40\mu$, arising from a well developed basal stroma."

[11] Del. Agr. Exp. Sta. Rep. 4:60–62. 1891.

Material was obtained from tomatoes of the yellow variety growing in the Cornell University gardens, answering in general to Chester's description, with the exception that the setæ are sometimes absent, and the basidia are rather longer than the measurements given in the original description. The colonies are quite different from those of the Glœosporium on tomato, as well as from those of *Col. lagenarium.* There is a scant development of decumbent, spreading mycelium, with a strong tendency to concentric markings in the growth, where the mycelium is more erect and in tufts, surrounding black, spherical perithecia-like bodies which produce long setæ. These, so far as has yet been determined, are sterile. The conidia formed freely on the mycelium do not mass up in large heaps. Toward the margin clusters are formed of knotted and swollen mycelium bearing quantities of dark colored buds or gemmæ. These lie quite close together, but are more or less distinct. They resemble the colonies of the Volutella on citron in this respect. On bean stems very little mycelium is developed, but the stems are plentifully covered with black spherical or hemispherical pustules, which bear long setæ. In some of these bodies setæ are absent. These bodies seem to be sterile, like those described in the colonies on nutrient agar. On the surface of the infusion a light colored mycelium forms a thick compact mat which does not have a flocculent appearance. but which is rather smooth and shining, and shows white compact aggregations of threads which with age turn black as those on the stems.

Another Colletotrichum was found on muskmelon, which from the similarity in artificial growth developments was referred to this species.

Volutella violæ, n. sp. (*figs. 22–23, 85–89*); on violet (*Viola cucullata*).

The Volutella on the violet is manifested on the leaves of the host by pale brown patches surrounded by a dark brown margin. In the center of the spots the black pustules of the

fungus are formed, usually on the upper surface of the leaf, though they also occur on the lower side.

It is distinguished as a Volutella by the marginal setæ, and by the elevated character of the sporodochia, although in some cases the basidia are scarcely more elevated above the host than is found to be the case in some species of Colletotrichum. The conidia are continuous, hyaline, curved, acute at each end, measuring $15–21 \times 3–4\mu$.

Upon germination the conidium contents become coarsely granular, and a germ tube pushes out at or near the end on the concave side. Sometimes a second and a third germ tube succeeds the first. These soon become irregularly septate. With the growth of the fungus the mycelium becomes short celled and closely intermingled, forming at irregular intervals patches of stroma. The mycelium at these places, which is at first colorless, becomes irregularly swollen and colored; from the center of this mass the conidium bearing basidia are formed. Certain cells of the stroma give rise to the setæ, which are enlarged at the base, usually twice or three times septate. Large colored club-shaped bodies are formed at the ends of certain threads of the mycelium, which frequently form grotesque masses by elongation and budding.

The colony of the fungus is one of the most beautiful ones studied. Three or four days after germination the small colonies present a stellate appearance; this character is gradually effaced and the mycelium forms a uniform colony of compact radiating threads. The acervuli are confined to a central region in the colony, in irregular arrangement, where a pink pigment is developed. This gradually extends over the colony, changing to violet, and producing a beautifully iridescent play of colors.

In tube culture a sparse grayish mycelium spreads over the stems, and forms a compact shining mass over the surface of the infusion which displays the iridescence seen in the colonies. With age this coloring disappears in the tubes but is quite lasting in Petri dishes. This delicacy of coloring is less marked

in colonies produced from conidia, which have for some time become adapted to artificial culture.

On sterilized stems the fruiting stools are formed similar to those found on the leaves but of a more vigorous habit. The setæ attain a length of 320μ. From the acervuli the conidia exude in dull pink masses.

The early growth characters and the development of the pigment show a close relationship with that of the Volutella of carnations described by Professor Atkinson. The colonies, however, of the latter show in photograph more decidedly stellate characters in the mature colonies, while in the former the stroma and setæ are black, instead of hyaline as in that species.

VERMICULARIA CIRCINANS Berk. (*fig. 16*).

The anthracnose of onions, which occurs quite frequently on the white varieties, was first described by Mr. M. J. Berkeley.[12] An account was subsequently given of the same disease by Dr. Thaxter.[13] The disease first appears as a small black dot, usually on the outer scales, which becomes encircled by rings. These concentric markings are caused by the acervuli, which as the disease spreads are scattered with less regularity over the scale. The pustules are plentifully supplied with setæ, and the conidia ooze out in dull flesh colored masses. They are elliptical, slightly curved, or inequilateral, measuring $20–22 \times 3\mu$.

A section reveals a remarkable development of a stroma extending down into the tissue to a distance of $250–300\mu$. This development extends above the tissue to some extent. There is not, however, a perithecium developed, and although the fungus has been placed among the Sphæropsideæ, the character of the pustule shows a close resemblance to those species of Colletotrichum in which an abundant basal stroma is developed, while the marginal setæ and the elevated basidia, as well as the characters in artificial cultures, intimately associate the fungus with the genus Volutella.

[12] Gardener's Chronicle 11 : 595. 1851.

[13] Conn. Agr. Exp. Sta. Rep. 13: 163. 1889.

In germination the protoplasm pushes out through one or more germ tubes usually near the end of the spore, in the usual manner. The colony, as it first appears to the unaided eye, presents a somewhat stellate appearance, but later from the point of inoculation a nearly uniform appearance is presented over a larger part of the colony, with a delicately fringed margin of spreading mycelium. The mycelium which grows both above and below the surface of the agar is at first nearly colorless; with age it becomes a dark smoky color. The discoloration usually appearing some distance from the point of inoculation, extends outward in irregular radiations. The ends of the threads become enlarged, colored, and delimited by a septum. These enlargements are also intercalary and at times peculiarly lobed and branched. At the center of the colony are grouped the dark colored fruiting bodies. At these points a stroma is formed and from some cells of the stroma setæ are borne as in nature. On bean stems the fungus produces a grayish mycelium which spreads over the surface of the infusion, becoming in time of a dark smoky color. A thin stroma spreads over the stems, and acervuli are produced abundantly, and are at times confluent. The setæ, which are quite conspicuous, are borne usually on the margin, sometimes at the center of the pustule.

ASCIGEROUS FORMS.

The course of development of many of the Ascomycetes, especially the Pyrenomycetes, is pleomorphic, and various conidial forms have been definitely interpolated with ascigerous stages. The structure and habits of the species of Glœosporium and Colletotrichum suggest that they too are form genera, having biological relations with perfect forms, although little has been definitely proven in this group to establish the connection.

Since the mycelial growth takes place largely near the surface of the host, and the conidia, provided with delicate walls, require no resting period previous to germination, evidence is strong that in the course of their life history, or at least in some

stage of their phylogenetic development, this group has, or once had, a complemental perithecial or pycnidial stage.

In 1886 Von Tafel[14] carried on some investigations with *Glœosporium nervisequum* (Fckl.) Sacc., which he suspected from morphological evidence to possess an organic relationship with a pycnidial form, *Discula platani* (Pk.) Sacc. Owing to the fact that the pycnidial form was always associated with the Glœosporium form on the leaves, he was led to suppose that the mycelium passed through the petioles to the branches and there formed the pycnidia whose conidia developed in turn the Glœosporium. He was unable, however, to establish the connection by cultures, and the question still remained an open one. In continuing the investigations there was a suggested connection of the Discula with an ascigerous form of the genus Fenestella. The apparent connection of this form with a second pycnidial form as well as with a form resembling Acrostalegma, tended to disprove rather than to establish the connection with the Glœosporium.

In connection with the study of *Glœosporium fructigenum* Berk., Miss Southworth[15] notes the finding of a perithecium containing two asci on the apple from which the Glœosporium was obtained, but the material, owing to contamination, could not be further examined. While the association of the two forms on the same host is interesting, very little value can be given to the incident in establishing a connection between them, for, as she says, the apple became contaminated and it is quite possible to account for the presence of the ascigerous form in that way.

Suggested connections are found in Saccardo's *Sylloge* of species of Glœosporium with ascigerous stages. *Gnomoniella ? circinata*[16] on the leaves of Ribes is noted in connection with *Glœosporium ribis* and *Gnomoniella fimbriata* has been found associated with *Glœosporium carpini* on the leaves of Hedera.

In a large number of artificial cultures of *Glœosporium fructi-*

[14] Bot. Zeit. 44: 284. 1886.

[15] Dept. Ag. Rept. Washington 348. 1887.

[16] Sacc. Syll. Fung. 1: 416–419.

genum no perithecial form was found in connection with it by the writer. In the study of *G. nervisequum* (Fckl.) Sacc., both pycnidial and perithecial forms were found associated with it in the first dilution cultures, but when pure cultures were obtained by subsequent dilutions only the conidial form was found in the cultures.

It is an interesting and significant fact that two species of Glœosporium should be found associated with the same ascigerous genus Gnomoniella. The writer made several attempts to obtain a culture of *G. ribis*, all of which failed and its culture was abandoned.

Gnomoniopsis cingulata Stoneman (*figs. 27, 28, 90–97*); *Glœosporium cingulatum* Atk. on *Ligustrum vulgare*.

In 1892 Professor Atkinson[17] described a new species of anthracnose of the privet (*Ligustrum vulgare*). The growth characters of the fungus in artificial cultures suggested the probable cycle of development of this Glœosporium. On cultures of sterilized bean stems the threads were associated into strands of compact tufts, several layers deep. Within these wefts were numerous black rotund perithecia-like bodies, white within and filled with rich protoplasmic contents, presaging, as the author suggested, a probable ascigerous stage. Subsequent to the publication of this study, mature perithecia were obtained in pure cultures of this Glœosporium, sections of which were mounted and preserved. The material studied was obtained from Penn Yan, N. Y. The discovery of the perfect stage in pure cultures rendered the investigations of Professor Atkinson of more value than any results which had been previously brought to bear on the subject.

In February 1895, material was received from Manhattan, Kansas, through Professor Hitchcock, of the State Agricultural College. The affected stems showed the elongated depressed areas of a light brown color corresponding to the affected twigs originally described. No spores could be obtained owing to the

[17] Cornell University Exp. Sta. Bull. 49: 310. 1892.

age of the fruiting pustules, but with a flamed scalpel, after cutting away the surface tissues, portions of the affected areas were removed and transferred to tubes of sterilized bean stems on February 18. A grayish mycelium soon began to spread over the stems, and black perithecia-like bodies made their appearance in connection with the acervuli producing the masses of conidia. On March 18 an examination of the cultures was made, and the black elevated wefts of mycelium were found to be perithecia containing mature asci, agreeing in every respect with those previously mounted by Professor Atkinson.

The perithecia were cespitose, seated upon a subiculum or stroma of loosely interwoven mycelium, dark brown, flask-shaped, membranaceous, measuring from 250–320μ in length and about 150μ in diameter, gradually constricted toward the apex into a short rostrum. The perithecia were more or less hairy with a conspicuous tuft of coarse brown mycelium about the ostiolum. The asci were aparaphysate, clavate, sessile, measuring about $64 \times 14\mu$. Spores eight, hyaline, elliptical, slightly curved, subdistichous, $20–28 \times 5–7\mu$, usually with a clear spot at the center.

As it was impossible to say from what growth this result was obtained, it now remained to establish definitely the connection of the ascigerous stage and the conidial form. A dilution culture was therefore made in nutrient agar, and spores were marked which by their size and shape could be distinctly recognized as ascospores. These spores germinated in the same manner as do the conidia, by sending out a germ tube usually near the end, a little in advance of one originating near the opposite end. *Fig. 97* shows germinating ascospores eight hours after sowing; twenty-four hours later under favorable conditions they may attain a length of 500 or 600μ, showing indefinite septation and irregular branching. The germination of some spores may be retarded and the germ tube delayed until the day following the sowing, although the spores do not become altered in size or shape. On the second day after germination as many as four or five germ tubes may be seen to proceed from a single

spore. These usually become branched quite near their origin, but the center of the colony remains open and the radiating mycelial strands remain distinct from each other for about 2^{mm} from the center. Beyond this the mycelium branches in a brush-like manner, mingling toward the margin in a loosely spreading uneven fringe. The colonies produced from the ascospore had the same characteristic snowflake appearance described by Professor Atkinson for the colonies resulting from the conidia. From the tips of the mycelium the elliptical or clavate conidia are delimited as early as the second day after germination; the time, however, varies, depending upon the separation of the colonies and the amount of nutriment. When the colonies are well separated and growing in an abundance of nutriment, the formation of conidia is delayed. In artificial cultures the acervuli are sometimes attended with setæ, although they are not sufficiently abundant to characterize the genus as a Colletotrichum, and none have thus far been found in sections of the acervuli made from the host plant. Very little pigment is developed in the agar in connection with the formation of conidia, but ten or fourteen days after sowing the colony begins to show a development of stromata in small circular masses scattered indefinitely over the colony, which become elevated above the agar and overspread it with a grayish mycelium. These are filled with coarse granular protoplasm, and represent the early stage of the perithecia; the agar, however, usually dries away before they become mature, although asci have occasionally been found in them. These are formed in connection with conidia, alike on the colonies developed from either ascospores or conidia. Portions of the mycelium produced from marked spores were removed to cultures of bean stems, the colonies being sufficiently separated so as to insure pure cultures. These separation cultures produced the grayish mycelium, bearing conidia abundantly, which collect in pink masses. The mycelium after about ten days becomes a dark brown; numerous dark buds or gemmae (?) are formed, and the association of the perithecia-producing stroma becomes manifest within a week or

ten days after inoculation. The perithecia become mature when the cultures have attained an age of three or four weeks.

Again in November 1895 both stems and leaves were received from Kansas affected with *G. cingulatum* Atk. On the leaves the fungus appears in light brown arid spots, oval or fusoid, bordering the midribs. Fruiting pustules are formed on both surfaces of the leaf, though more abundantly on the upper surface. From cultures obtained from these conidia, ascospores were again obtained. The two forms have been obtained repeatedly in subsequent transfers made to preserve the species in artificial cultures, and definite connection of the two stages cannot be doubted. While the pleomorphic course of development can readily be traced, it cannot be said that one stage is necessarily intercalated between successive crops of the other.

Gnomoniopsis piperata Stoneman (*figs. 98–104*); *Glœosporium piperatum* E. & E.; on pepper (*Capsicum annuum* L.).

In October 1896, peppers affected with *Glœosporium* were received from Professor S. M. Tracy of the Mississippi Agricultural Experiment Station. The affected areas appeared as circular or oval spots in which pale yellowish fruiting pustules had ruptured the epidermis in elongated, irregular fissures, which were closely associated so as to be confluent at the older affected portions; around the margin they were arranged concentrically The conidia were elliptical to oval, measuring $12–23 \times 5–6\mu$. A dilution culture of the conidia was made October 10. The conidia germinated in the ordinary manner within twelve hours; subsequent growth was slow and lest the colonies should become contaminated transfers were made to bean stems on October 23, although at this late date no conidia could be found in the cultures. The colonies showed few positive characters, the mycelium growing almost uniformly from a small light colored central point, with the exception of a less abundant growth surrounding the center about $4–5^{mm}$ in diameter. On bean stems the fungus developed quite an abundant grayish mycelium, standing out in a flocculent mass. On the surface of the infusion it is of a lighter color, and is usually more compact than on the stems, although this

condition varies in different cultures; in tubes containing richer nutrient material there is a more abundant and more compact development of mycelium. This difference is quite marked in parallel cultures on bean stems and young bean pods. In the latter case the mycelium is very abundantly developed, quite or nearly concealing the fruiting pustules. In tube cultures made on October 23 pink masses of conidia made their appearance five days later. In connection with the pink acervuli many perithecia-like bodies were observed. From this series of separation cultures a second dilution culture was made. The colonies again showed the nearly undifferentiated mycelial growth with the exception of a less abundant growth about the center. This portion, which is nearly free from mycelium at first, becomes overrun as the colony advances in growth, but the colony always remains more open at this portion. The production of conidia was not delayed so late in the second series of dilution cultures, and a few were formed eight days after sowing. Whether their earlier appearance was due to the condition of the nutrient agar, or to the fact that the fungus was becoming adapted to artificial growth conditions was not ascertained. The aggregated conidia form pale acervuli scattered quite thickly over the colony with the exception of the lighter portion near the center. In cultures ten or twelve days old the conidia become much longer than normal, and once or twice septate. From these cultures in which the colonies were so separated that pure separation cultures could be with certainty obtained, transfers were made on November 18 to an infusion of bean stems. On December 15 an examination of the tube revealed fully developed perithecia in connection with conidial clusters and the colored club-shaped bodies. The perithecia were so covered by the mycelium that their presence was not detected until a portion of the growth was removed with a needle and examined with the microscope. In order to check the experiment a second sowing was made of conidia which had undergone desiccation in the laboratory for five months. These germinated and conidia and perithecia were obtained as before.

The perithecial form closely resembles that of *G. cingulatum* Atk. On first examination it was thought that, though of the same genus, a specific distinction existed in the more slender perithecia of the former and the smaller spore measurements. These characters vary, however, in different cultures, and the larger measurements of the perithecial stage of *G. piperatum.* E. & E. are common to the smaller perithecia and spores of the privet anthracnose.

Ascospores sown in nutrient agar produced the conidia, and later on perithecia, which matured in thirteen days in the agar cultures, the colonies from ascospores having the same appearance as those from conidia. These colonies differ from those of *G. cingulatum* Atk. in the more uniform growth and the compact interweaving of mycelium at the outer portion of the colony. A description of the perithecial stage is as follows:

Perithecia cespitose, thinly membranaceous, dark brown, of a lighter color toward the ostiolum, at least in younger forms, pear-shaped, hairy, situated upon or partly immersed in a light-colored stroma of loosely interwoven threads. Asci aparaphysate, clavate, sessile; sporidia eight, hyaline, single-celled, slightly curved, elliptical, subdistichous, $12–18 \times 4–6\mu$.

Gnomoniopsis cincta Stoneman (*figs. 31, 110–114*); *Colletotrichum cinctum* (Berk. & Curtiss); on orchid (*Maxillaria picta, Oncidium* sp.).

In connection with a study of the leaf spot of the conservatory orchid by Mr. Paddock, a student in the laboratory, one of the affected leaves, when placed in a moist chamber, developed an anthracnose. The anthracnose had apparently no connection with the so-called "leaf spot" of the orchid, which is probably of non-parasitic origin.[18] Later other anthracnosed orchids were found in cold house cultivation on species of the genera Maxillaria and Oncidium, having a similar appearance on the

[18] The disease has been found by Mr. Massee (*Annals of Bot.* 9:421. 1895) to be due to sudden changes of temperature causing a precipitation of moisture on the leaves.

leaf and in the growth characters manifested in artificial cultures. The pustules are erumpent, appearing on either surface of the leaf, indefinitely located on large, withered areas, or arranged in waving concentric circles. Conidia 12–15 × 3–4μ, elliptical, 2-guttulate. Setæ rising above the pink masses of conidia characterize the genus as a Colletotrichum, which agrees in other characters with the species described by Berkeley and Curtiss as *Glœosporium cinctum*. The setæ frequently nearly obscured by the abundant masses of conidia are doubtless in some cases absent.

On sectioning portions of the leaf, the Colletotrichum was found associated with a pycnidial stage and also a minute pyrenomycetous form. The perithecia of the latter measured 48–75μ in diameter, were flask-shaped, borne singly or in clusters of two or three, on both upper and under side of the leaf. The bases of the perithecia were wholly or partly submerged, the partially emerging necks causing minute elevations in the tissue of the leaf. The spores were immature, and in sections the characters could not be well determined; they were small, elliptical, slightly inequilateral, hyaline, single-celled, and measured approximately 6–7 × 2–3μ.

Dilution cultures of the conidia were made February 16. On February 17 germ tubes arising from one or both ends of the conidium had attained a length of 15–50μ. Laboratory dried conidia which were sown later required a longer period for absorbing nutrient material before germinating. Many showed no sign of germinating twenty-four hours after sowing, except in the coarsely granular contents of the conidia. These later, however, germinated in the ordinary manner. The young colonies resulting from the conidia present a small, white center, from which proceed five or six slender radiating strands of mycelium which branch out about 2^{mm} from the central point in fan-like tufts, remaining quite distinct in some colonies, while in others they mingle more or less at the margin, if the growth is luxuriant. The mycelium does not have such a loose, undulating growth as that of *G. cingulatum* Atk., which it resembles in

the open portion surrounding the center, but the colonies resemble those of the orange anthracnose (*Col. glœosporoides*).

On bean stems the fungus develops a pure white mycelium which in rich nutrient media covers the substratum with a close, white felt. In some of the tubes black perithecia-like bodies made their appearance on the stems, while in others they were mingled with pink acervuli, and again the acervuli appeared almost exclusively. On bean stems, to which transfers were made February 17, perithecia containing asci were found on March 21. In cultures two months old many of the perithecia-like bodies retain their white protoplasmic contents, the cessation of further development probably being due to the exhaustion of the nutrient media. The perithecia measure from 180–280μ in diameter, are flask-shaped, membranaceous, and cespitose. Asci aparaphysate, clavate, sessile, truncate or obtuse when mature, measuring 65–70μ in length, eight-spored. Sporidia hyaline, single-celled, elliptical, curved, measuring $15–20 \times 3\mu$. From the germinated ascospores the conidia were again obtained. The first results were verified by cultures made later from different material.

The ascigerous stage, as may be seen by comparing the description and illustrations, bears a close resemblance to the two previous forms. The characters of the colonies show a specific distinction, as well as the general appearance of the fungus on the leaf and the presence of setæ in the natural state.

It is possible that the perithecial stage obtained in artificial cultures is identical with that found in connection with the Glœosporium on the leaf. The difference in size and the presence of a stroma might be accounted for by the artificial conditions of growth.

Gnomoniopsis rubicola Stoneman (*figs. 29–30, 105–109*); *Colletotrichum rubicolum* E. & E.; on red raspberry (*Rubus strigosus*).

In December 1895 some anthracnoses were kindly forwarded me by Mr. J. B. Ellis, among them a new species, at the

time unpublished, on *Rubus strigosus*, accompanied by the following description: "Forming large, dark brown patches on the upper surface of the leaf; sori small, dark, suberumpent; conidia oblong, elliptical, $12.5 \times 6\mu$. Col. W. Va., Oct. '95, F. W Nuttall."

Conidia sown in a dilution culture of potato-agar on January 30, four hours later had developed germ tubes usually from one end of the conidium, and slightly constricted at the base, proceeding in irregularly flexous manner, occasionally septate, with little or no branching for a distance of 100–150μ. On January 16 the growth could be seen in the agar with the unaided eye, the low temperature of the laboratory possibly accounting for the slow progress of the fungus. The mycelium showed a long, narrow, loosely branched growth, 3–4^{mm} in length. A colony from one of the conidia, which had been marked at the time of germination, was transferred to sterilized bean stems. Four days later the mycelium had formed a rather dense, closely adhering weft of grayish mycelium; black fruiting bodies appeared upon the stems, which were also overspread with a mycelial growth. Upon examining these on February 10, the perithecia were found to contain mature asci, the ascigerous stage agreeing generally in appearance with the two previous forms. There is lacking in this species the conspicuous tuft of mycelium at the apex of the perithecia, which are usually larger than those of the pepper anthracnose.

The ascospores germinated in potato-agar, as had the Colletotrichum conidia, by sending out obliquely from one end a germ tube; the tube again is slightly constricted at the base, and extends from 180–200μ in length before branching takes place. This growth produces a colony, which, like that from the Colletotrichum conidia, is at first narrow, elongate, and loosely spreading. About four days after germination, conidia are delimited from the mycelium in great abundance. Later, colored swollen buds are formed. The reproduction of conidia here took place much sooner than in the original cultures of the conidia; and, inasmuch as the temperature of the laboratory

was nearly uniform at the two different times, their earlier appearance may be accounted for by its gradual adaptation o the artificial environment. Certain cells in the mycelium become swollen, usually septate and dark colored, and, in many cases, the fusion, with a smaller, curved, mycelial branch suggests a process of fertilization, although no careful study of this point was undertaken. From the swollen cells numerous colored branches arise which twine about and conceal it. At these places in the mycelium perithecia are formed.

The appearance of the colonies is quite peculiar to the species. The mycelium radiates from a small central point, in a feathery manner, forming one or two fan-shaped expansions which sometimes remain quite distinct for some time, or when growth proceeds in several radiations they become more or less united, and growth is more or less uniform. The margin of the colony has an even fringe of straight, nearly parallel threads.

The colony, which is at first flesh-colored, assumes a faint greenish tinge, which becomes a dark olivaceous brown at the more central portions, while the marginal growth retains the buff or slightly salmon tinge. The darker central portion is surrounded by the black fruiting bodies which are tufted with a grayish mycelium. The peculiar development of pigment is quite unlike that found in the three preceding species, or in fact in any species yet studied.

In connection with the perithecia grown upon bean stems, large conidial cushions were formed, surrounded with dark spreading hyphæ arising from a stroma at the base of the cushion. The conidia in artificial cultures frequently become septate.

Gnomoniopsis? vanillæ Stoneman (*fig. 32*); *Colletotrichum* on Vanilla.

An anthracnose was obtained from a vanilla plant growing in the conservatory which belonged to the genus Colletotrichum. It appeared in small black erumpent pustules on both sides of

the withered leaves, on the stems, and on the aerial roots. The pustules measured 150–180μ in diameter; a section through the pustules shows a well developed basal stroma, bearing closely crowded septate basidia 30–45μ in length. The setæ are colored, three or four times septate near the base. In older pustules the stroma passes up around the basidia, forming a cylinder of a compact association of rather regular rectangular cells. The pustules are somewhat superficially situated, the basidia extending nearly their whole length above the epidermis of the host.

Closely associated with the Colletotrichum was found a pyrenomycetous form. The perithecia bore a close resemblance to those described by Massee[19] in connection with another conidial form belonging to this group, the genus Hainesia. They were flask-shaped, having a membranaceous wall several layers in thickness, borne singly or in clusters, but without a stroma. Asci clavate, sessile, $75–80 \times 15–16\mu$, attenuate at base, paraphysate, 8-spored; paraphyses long, slender, filiform; sporidia elliptical, hyaline, or slightly fuliginous, curved $21–24 \times 6–7\mu$. The form described by Massee belonged to the genus Calospora, and differed in the presence of a stroma and in the tri-septate sporidia. The perithecia found on the leaves were not valsoid as in Calospora, but when two or three were aggregated the necks diverged.

The close resemblance of the two forms and the association of a Colletotrichum suggested an interesting study, and a dilution culture was made of the conidia in meat-agar. The leaves, which were more or less decayed, were an easy prey to saprophytic fungi, so that the first dilution was liable to be contaminated. The conidia, however, were found in great abundance in plates one and two, and germination was observed. Owing to their crowded condition, however, and the liability to contamination, these plates were discarded. Plate three contained but one colony. It had attained in eight days a diameter of 2^{cm} and was nearly uniform in growth. As frequently happens with a

[19] Kew Bull. Misc. Information 139: 111–120. 1892.

good supply of nutriment, when a profuse vegetative growth takes place, the production of conidia is delayed. Transfers, however, were made to bean stems in order to determine its further growth characters, and to avoid the possibility of contamination from exposure to the air. As germination had not been observed it was impossible to say from what the colony had originated.

On bean stems there was developed a rather compact white mycelial growth, and black fruiting bodies made their appearance in connection with the Colletotrichum conidia. The former developed into perithecia containing paraphysate asci with single-celled, curved spores. These spores when sown produced conidia, but from the conidia the perfect stage has not yet been obtained. Further investigation will be necessary in connection with this species, and a further detailed description will be deferred to another paper.

The colonies from both ascospores and conidia, in their uniform growth, with the exception of a slightly open growth around the central point, resemble those described in connection with *Glœosporium piperatum*.

CONCLUSIONS.

I will sum up briefly some of the more important results obtained in connection with this study: The group of fungi under discussion, commonly known as anthracnoses, in many cases present, in artificial cultures, distinct characters of growth for distinct species, which may be made of value in distinguishing species whose similarity in morphological structure in connection with their host often renders their systematic position uncertain.

The artificial growth characters of a single species fluctuate within certain limits with varying conditions of temperature and nutrient media, and certain characters which are prominent may become obscured with age, so that to render the characters of taxonomic value uniform growth conditions are essential.

The formation of the so-called secondary spores or buds

which are common to Glœosporium, Colletotrichum, Volutella, and Vermicularia is not a constant character, but may be absent throughout the entire cycle of development of a species, or they may be forced in these same species by a lack of nourishment.

The presence of a perithecial stage has been proven in four different species, of which the host plants vary widely in habits and structure. One of these exists as a saprophyte in a natural state (the one in connection with the vanilla anthracnose is omitted), while the other three are saprophytes in artificial cultures; whether they occur in nature has not been determined. Two of the perithecial forms were connected with species of the genus Colletotrichum, and two with Glœosporium.[20]

The colonies produced in the species with which perfect forms have been connected agree in producing a loose open growth about the center, but all show specific differences in formation of stroma, pigment, or arrangement of fruiting sori.

While the conidial forms show greater variations in structure than do the perithecial stages of the different species, the growth characters of the colonies from ascospores resemble those of the conidial stage with which they are connected more closely than they resemble each other.

The perfect forms approach the genus Gnomoniella, agreeing in the submembranaceous, subglobose, subcutaneous-erumpent perithecia; in the cylindrical, clavate, 8-spored asci; and the continuous hyaline conidia. They differ in the curved conidia, which in Gnomoniella are typically ovate, oblong subfiliform and straight, although in species of Gnomoniella, *G. amœna* (Nees) Sacc. and *G. fasciculata* (Fckl.) Sacc. they are curved. The genus under consideration does not show the slender, somewhat elongated beaks found in Gnomoniella, which are surrounded at the base with a white, cleft collar formed of the ruptured epidermis of the host, and the necks are hairy, while in Gnomoniella they are smooth. In shape the perithecia resemble the genus Camptosphæria, but they differ from this

[20] The presence of setæ in the cultures has been so variable as to raise the question whether they form a well-founded basis for distinguishing these two genera.

genus in other characters more than they do from Gnomoniella. Excluded from these two genera its position would be in a genus between these two for which the writer proposes the name Gnomoniopsis with the following diagnosis:

GNOMONIOPSIS, n. gen.

Perithecia cespitose, membranaceous, dark brown, rostrate, of a lighter color at the apex in early stages, flask-shaped, hairy, situated upon or partly immersed in a stroma; asci sessile, aparaphysate?, clavate, sporidia eight, hyaline, oblong, single-celled, slightly curved, elliptical, subdistichous, including the following species: conidial form, certain species of Glœosporium:

G. cingulata (p. 101), *G. piperata* (p. 104), *G. rubicola* (p. 108), *G. cincta* (p. 106), *G. vanillæ* ? (p. 110).

From the evidence of these perfect forms it is probable that the genera Glœosporium and Colletotrichum have developed from one common ancestral genus of the pyrenomycetous form described above. Since of about thirty species studied but five have developed the complemental ascigerous stage, it is suggested that they have, to a large extent, become divorced from a perfect stage, and have become so adapted to environment that they are able to maintain themselves from year to year without the intervention of this stage. Many of the anthracnoses are parasitic on garden and orchard fruits, and are thus preserved with their host during the winter. Under less favorable circumstances the conidia may tide the fungus over, since they will stand a certain amount of desiccation. The stroma and sclerotia may also assist in ther preservation.

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EXPLANATION OF PLATES VII–XVIII.

The first plate is from photographs of the Petri dish cultures, generally of pure cultures, the colonies being natural size. The pen drawings are made to two different scales, the sections of hosts and the perithecia being made all to one scale, while the conidia and details of germination are made to another scale.

PLATE VII.

FIG. 1. *Glœosporium fructigenum* Berk. from apple; culture 1, three days old.

FIG. 2. Same, four days old.

FIG. 3. Same, from quince; culture 1, three days old.

FIG. 4. Same; culture 3, six days old.

FIG. 5. *G. phomoides* Sacc. from tomato; culture 1, three days old.

FIG. 6. Same; culture 3, six days old.

FIG. 7. Same; an old colony, showing development of the stroma.

FIG. 8. *G. venetum* Speg.; culture 3, one week old.

FIG. 9. *G. naviculisporum* Stoneman; culture eight days old.

FIG. 10. Same, or *Hainesia rubi* (West.) Sacc.

G. venetum, *G. naviculisporum*, and *G. rubi* all from *Rubus* sp.

FIG. 11. *G. musarum* Cke. & Mass.

FIG. 12. *G. fœtidophilum* Stoneman; culture six days old.

FIG. 13. *G. nervisequum* (Fckl.) Sacc. from *Platanus.*

FIG. 14. *G. cactorum* Stoneman.

FIG. 15. *Colletotrichum glœosporioides* Penz.; culture three days old.

FIG. 16. *Vermicularia circinans* Berk.; colony showing beginning of stroma.

FIG. 17. *Colletotrichum lagenarium* (Pass.) Sacc. & Roumg. from watermelon; culture five days old.

FIG. 18. Same; culture from another series nine days old.

FIG. 19. *C. lindemuthianum* (Sacc. & Magn.) Scribner; culture four days old.

FIG. 20. Same; culture from another series nine days old, showing the pronounced stroma which is absent from the colonies of *C. lagenarium*.

FIG. 21. *C. lycopersici* Chester from tomato.

FIG. 22. *Volutella violæ* Stoneman, plate culture.

FIG. 23. Same; older culture.

FIGS. 24, 25. *V. citrulli* Stoneman from citron; the same plate at different ages.

FIG. 26. *Gnomoniopsis cingulata* Stoneman; colonies from conidia taken from the stem.

FIGS. 27, 28. Same; colonies grown from four ascospores; *fig. 28* shows early formation of the stroma which bears the perithecia.

FIG. 29. *G. rubicola* Stoneman.

FIG. 30. Same; culture five days old.

FIG. 31. *G. cincta* Stoneman.

FIG. 32. *G. ? vanillæ* Stoneman; from culture four days old.

PLATE VIII.

FIG. 33. *Glœosporium fructigenum* Berk.; conidia germinating three hours after sowing.

FIG. 34. Same; twenty-four hours after sowing.

FIG. 35. Same; conidia sown in water producing colored buds and anastomosing mycelium in three days.

FIG. 36; Same; old mycelium in plate culture.

FIGS. 37, 38. Same; sections of old acervuli bearing large colored bodies at tips of basidia.

FIG. 39. *G. phomoides* Sacc.; conidia.

FIG. 40. Same; conidia germinating after twenty-four hours in agar.

FIG. 41. Same; section of pustule on tomato.

PLATE IX.

FIG. 42. *G. venetum* Speg.; conidia germinating in hanging drop.

FIGS. 43–45. Same; conidia germinated in agar three days after sowing.

FIG. 46. Same; section of acervulus.

FIG. 47. *G. naviculisporum* Stoneman; section of acervulus on host (*Rubus occidentalis*).

FIG. 48. Same; conidia.

FIG. 49. Same; conidia in hanging drop; *a*, anastomosing conidia; *b*. short basidium bearing a "secondary spore."

FIG. 50. Same; conidia in agar twenty-four hours after sowing.

FIG. 51. *Hainesia rubi* (West) Sacc.; section.

FIG. 52. Same; conidia germinating.

PLATE X.

FIG. 53. *G. nervisequum* (Fckl.) Sacc.; section of leaf showing acervulus on *Quercus alba*.

FIGS. 54–56. Same; conidia and early stages of germination.

FIGS. 57, 58. Same on *Platanus*.

FIGS. 59, 60. Same; conidia showing early stages of germination in agar.

FIG. 61. Same; conidia in agar twenty-four hours after sowing.

PLATE XI.

FIG. 62. *Colletotrichum lagenarium* (Pass.) Sacc. & Roumg.; conidia.

FIG. 63. Same; conidia germinated after twenty-four hours.

FIG. 64. Same; conidium which has been in agar three days showing no swelling.

FIG. 65. Same; conidium and mycelium four days old.

FIGS. 66, 67. Same; mycelium in culture five days old.

FIGS. 68, 69. Same; section of pustule on host.

PLATE XII.

FIG. 70. *C. lindemuthianum* (Sacc. & Magn.) Scribner; conidia.

FIG. 71. Same; conidia in culture twenty-four hours old.

FIG. 72. Same; conidia, and mycelium in culture four days old.

FIGS. 73, 74. Same; section of pustule on pod of *Phaseolus vulgaris*.

PLATE XIII.

FIGS. 75, 76. *C. lagenarium* (Pass.) Sacc. & Roumg. on cucumber; section of pustule.

FIG. 77. Same; conidia anastomosing in hanging drop culture.

FIG. 78. Same; conidia in agar.

FIG. 79. Same; seta enlarged.

FIG. 80. *Volutella citrulli* Stoneman; section of citron rind showing character of pustule.

FIG. 81. Same; conidia in various stages of germination.

FIG. 82. Same; stroma formed in clusters in colonies.

PLATE XIV.

FIG. 83. *Glœosporium fructigenum* Berk.; section of pustule on fruit of quince.

FIG. 84. *Colletotrichum glœosporioides* Penz.; section of leaf of orange with pustule.

FIG. 85. *Volutella violæ* Stoneman; section of affected leaf,

FIG. 86. Same; conidia germinating.

FIGS. 87, 88. Same; stroma in agar.

FIG. 89. Same; seta enlarged.

PLATE XV.

FIG. 90. *Gnomoniopsis cingulata* Stoneman; section of leaf showing acervulus.

FIG. 91. Same; conidia germinating.

FIG. 92. Same; conidia produced in culture two days old.

FIG. 93. Same; ascospores germinating.

FIG. 94. Same; seta and conidia in old cultures from ascospores.

FIG. 95. Same; stroma produced in cultures.

FIG. 96. Same; perithecia grown on bean stems.

FIG. 97. Same; asci.

PLATE XVI.

FIG. 98. *G. piperata* Stoneman; section of fruit showing pustule.

FIG. 99. Same; perithecia from bean stem culture.

FIG. 100. Same; asci.

FIG. 101. Same; ascospores before and after germination.

FIG. 102. Same; conidia.

FIG. 103. Same; beginning of stroma.

FIG. 104. Same; conidia from ascospores in agar.

PLATE XVII.

FIG. 105. *G. rubicola* Stoneman; ascospores.

FIG. 106. Same; ascospores germinating in agar.

FIG. 107. Same; ascus enlarged.

FIG. 108. Same; beginning of formation of stroma in which the perithecia are developed.

FIG. 109. Same; section of perithecia grown on bean stems.

PLATE XVIII.

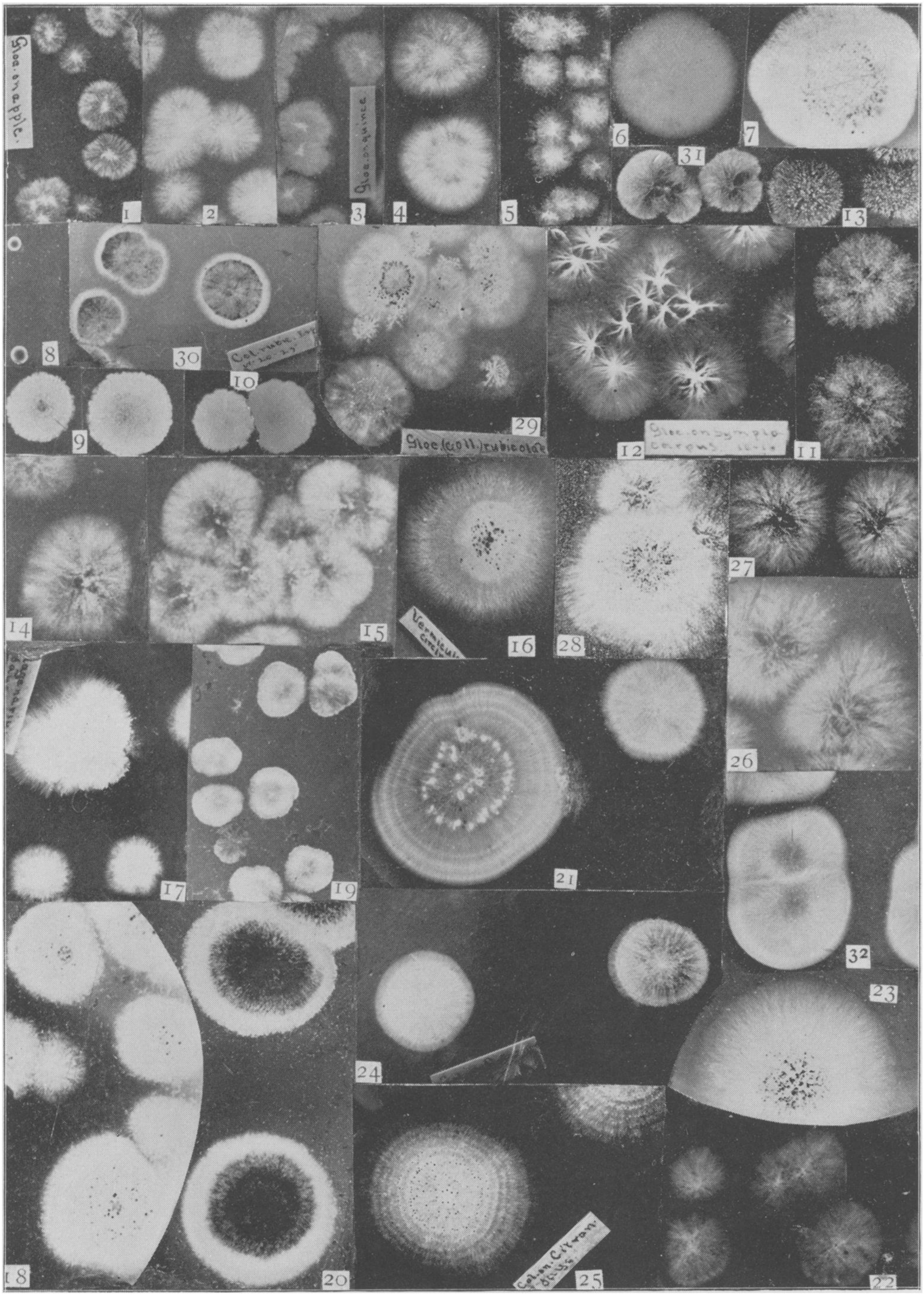
FIG. 110. *G. cincta* Stoneman; section of acervulus on leaf.

FIG. 111. Same; conidia germinating.

FIG. 112. Same; perithecia found on leaf of orchid in conservatory.

FIG. 113. Same; perithecia grown on sterilized bean stems.

FIG. 114. Same; immature ascus, and mature one with ascospores.



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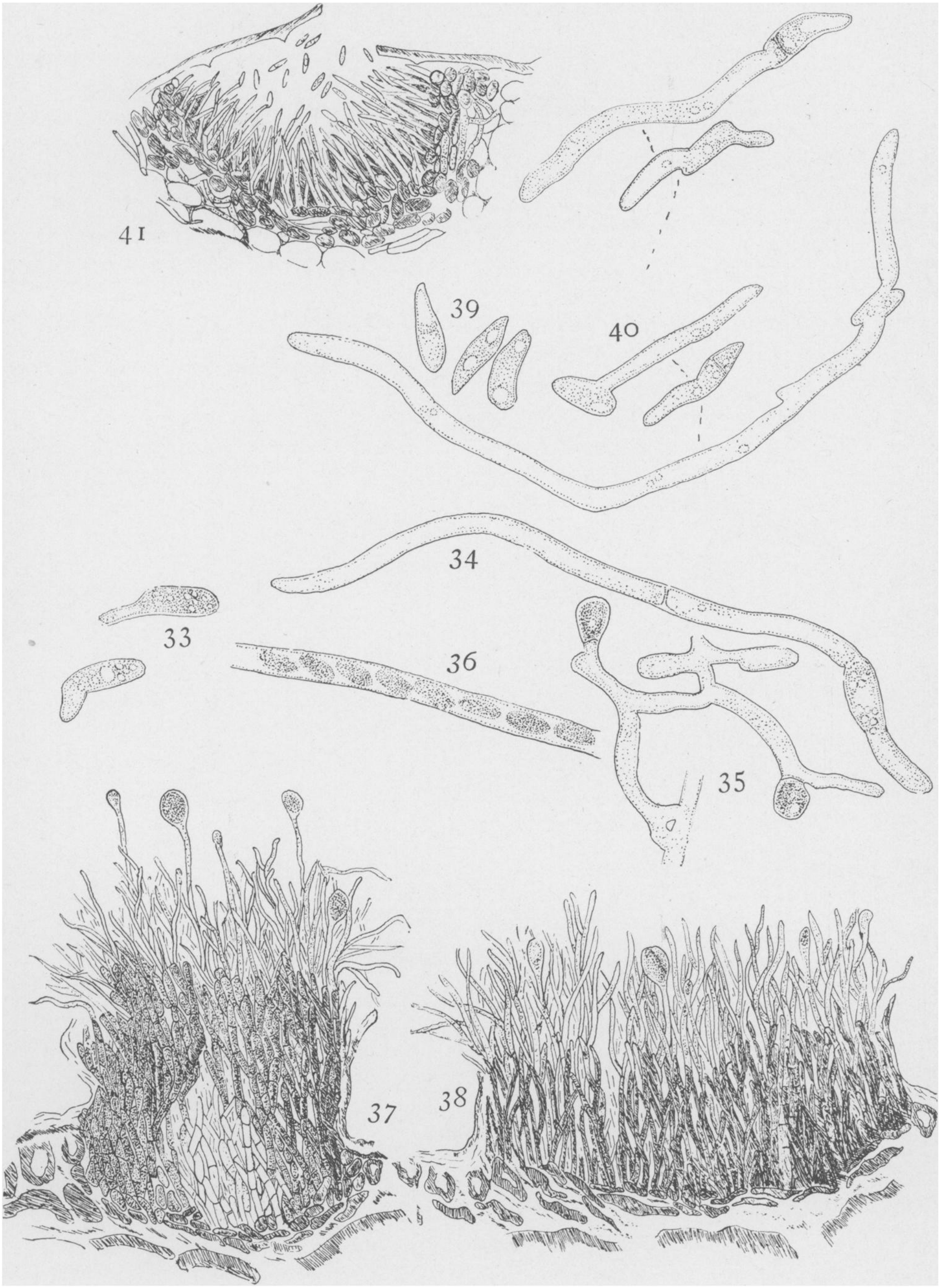

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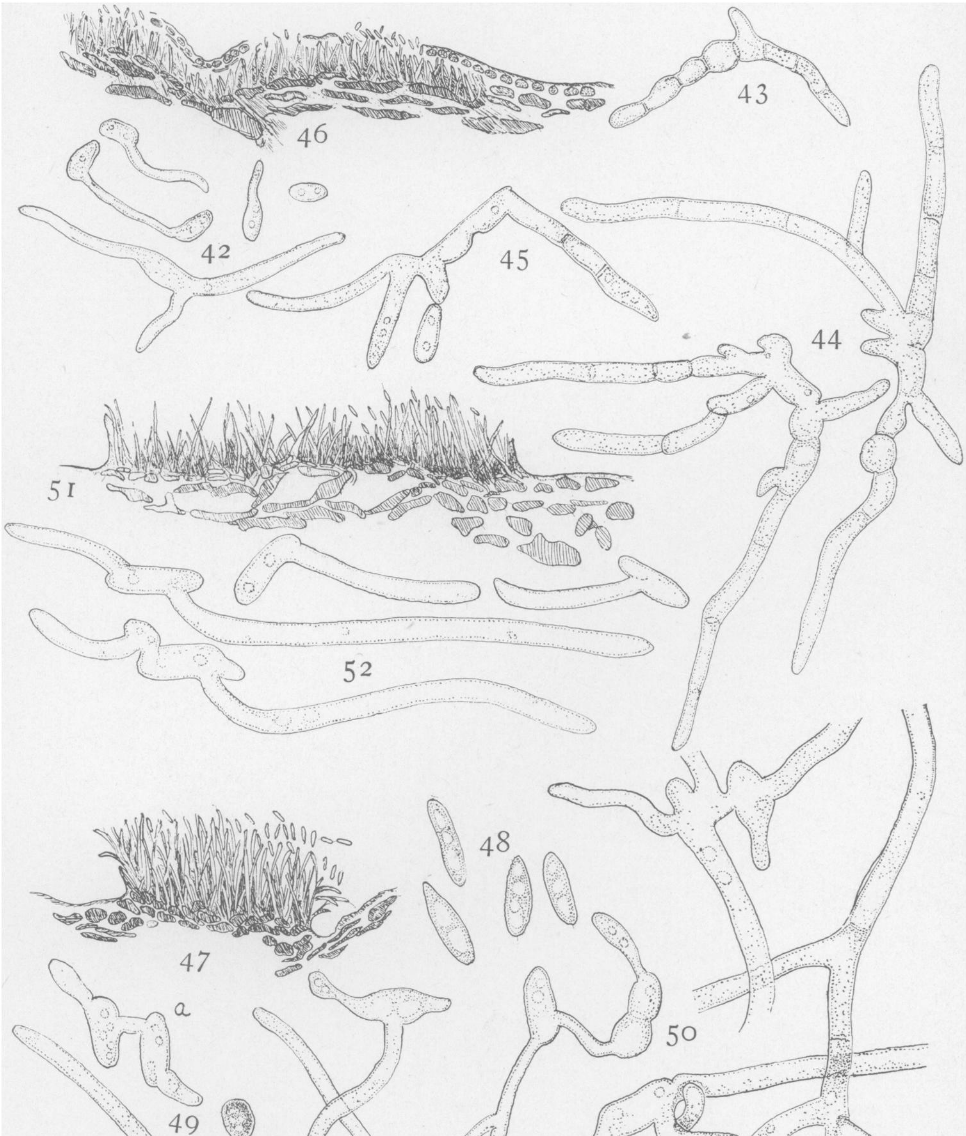

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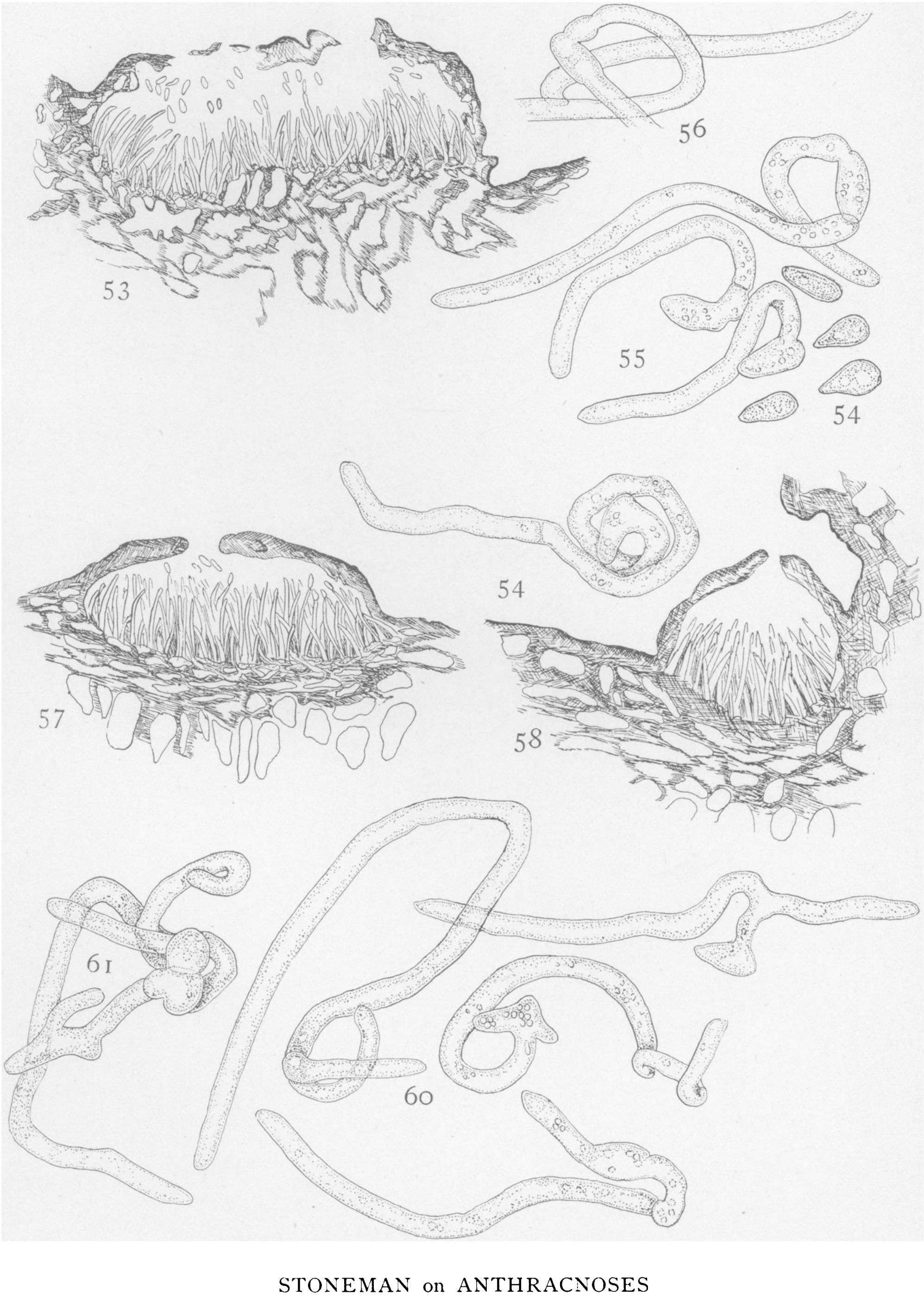

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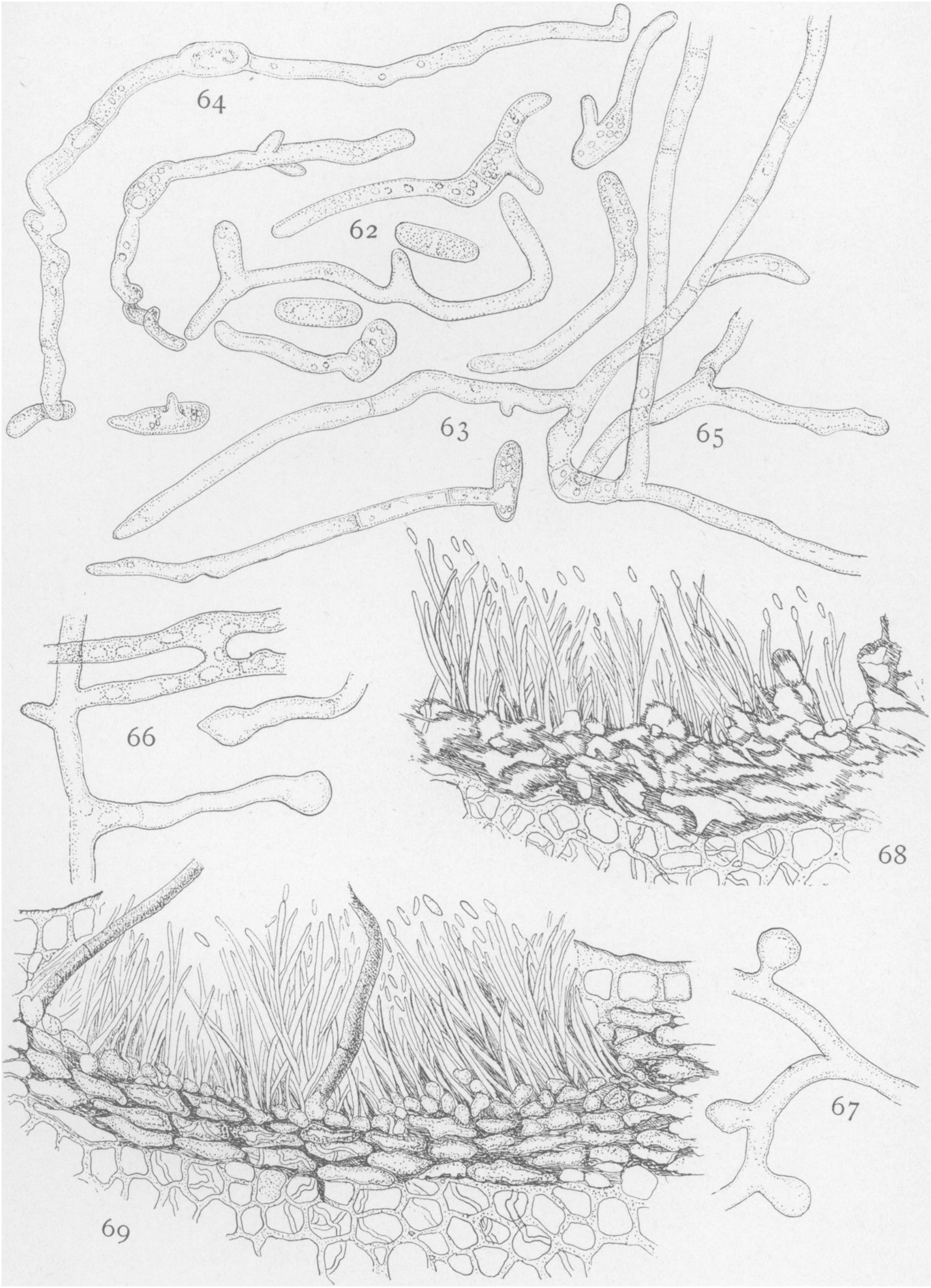

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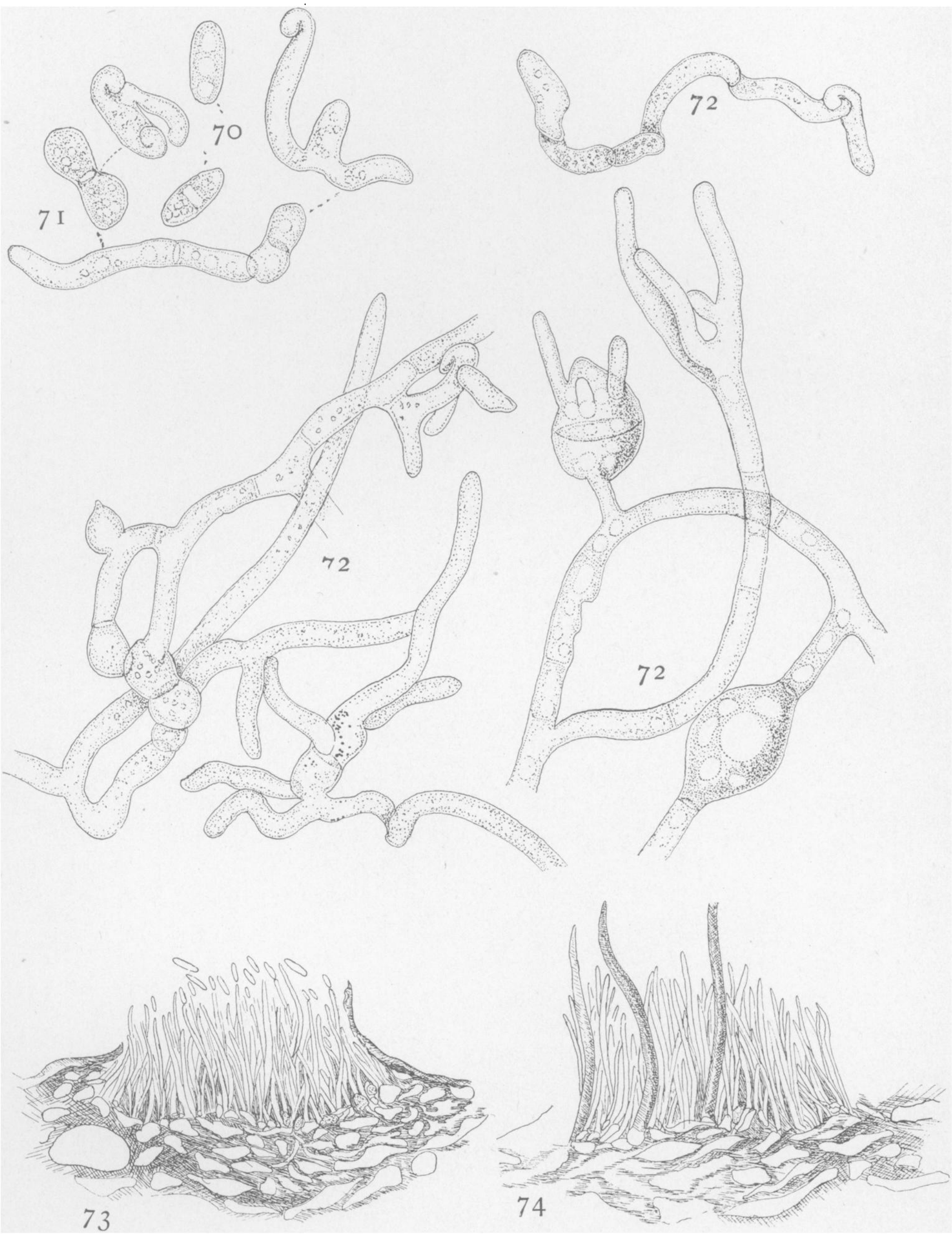

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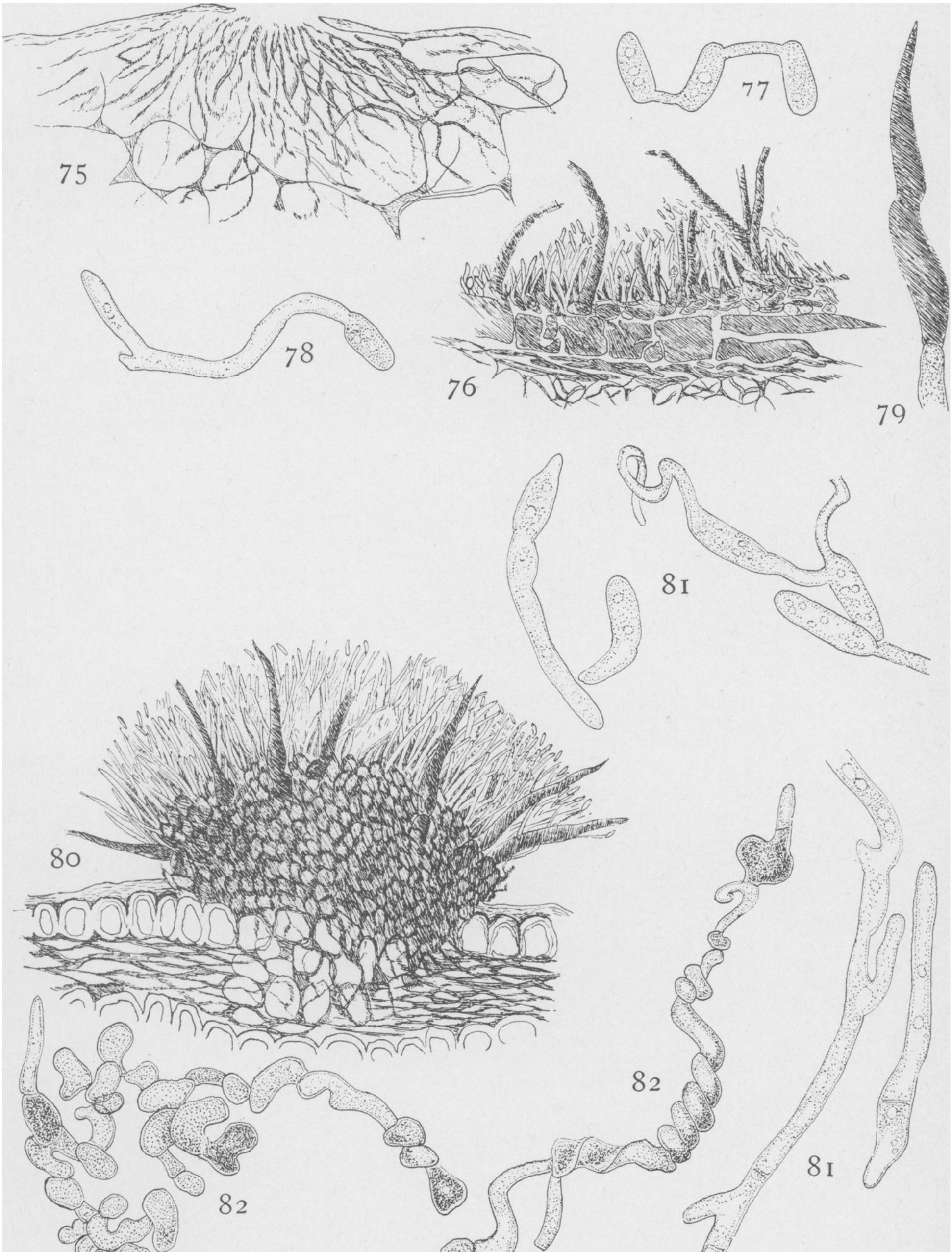

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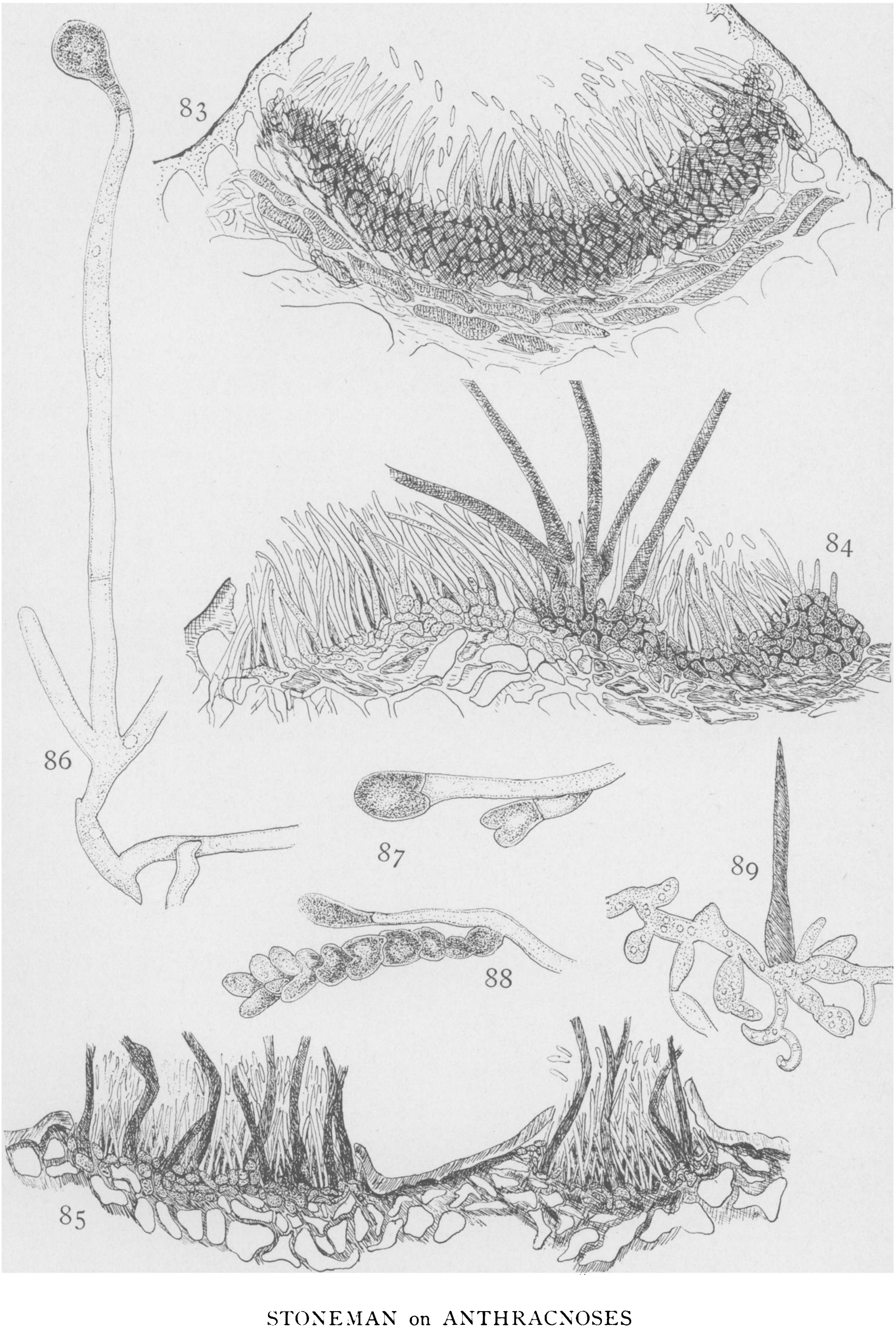

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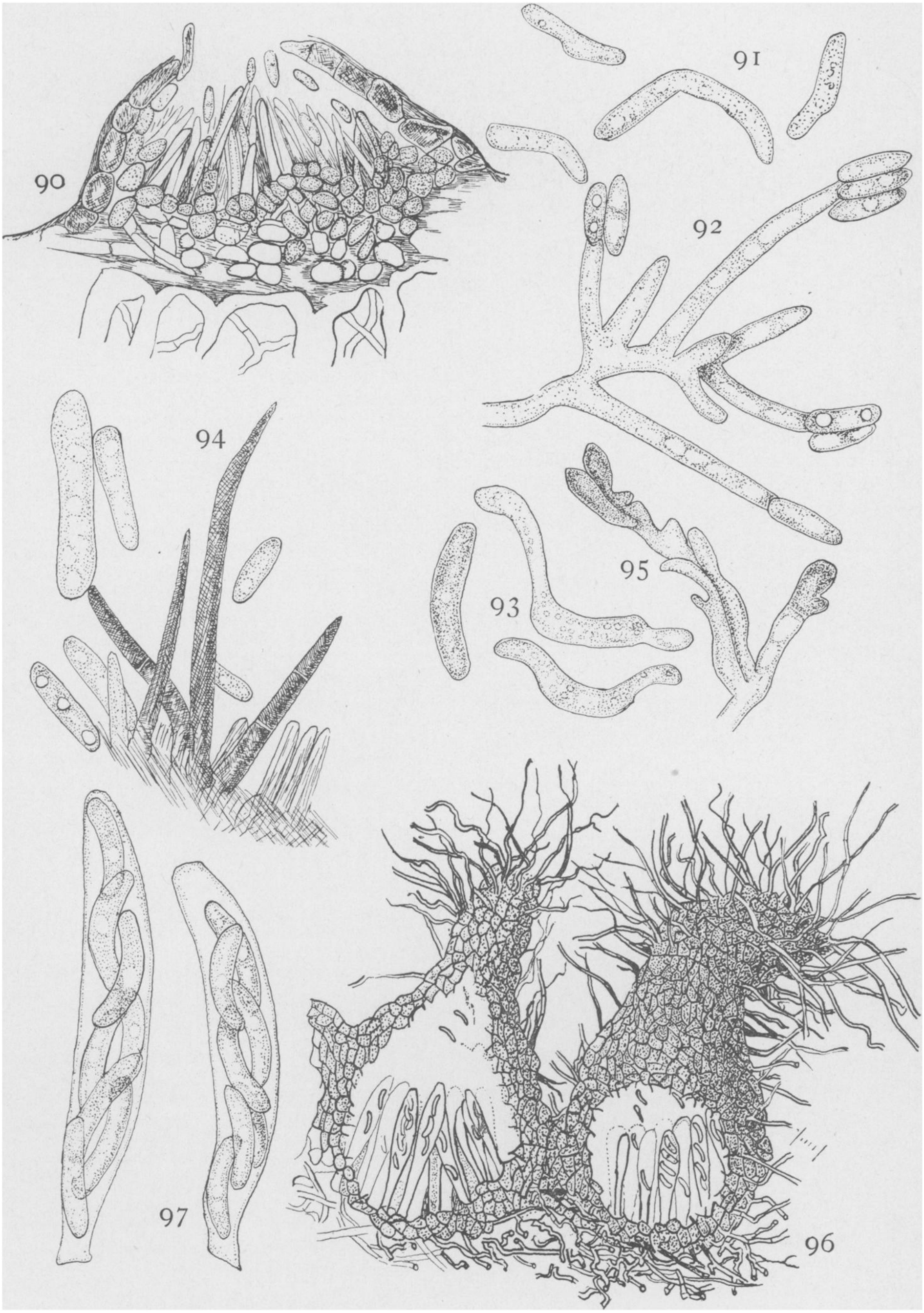

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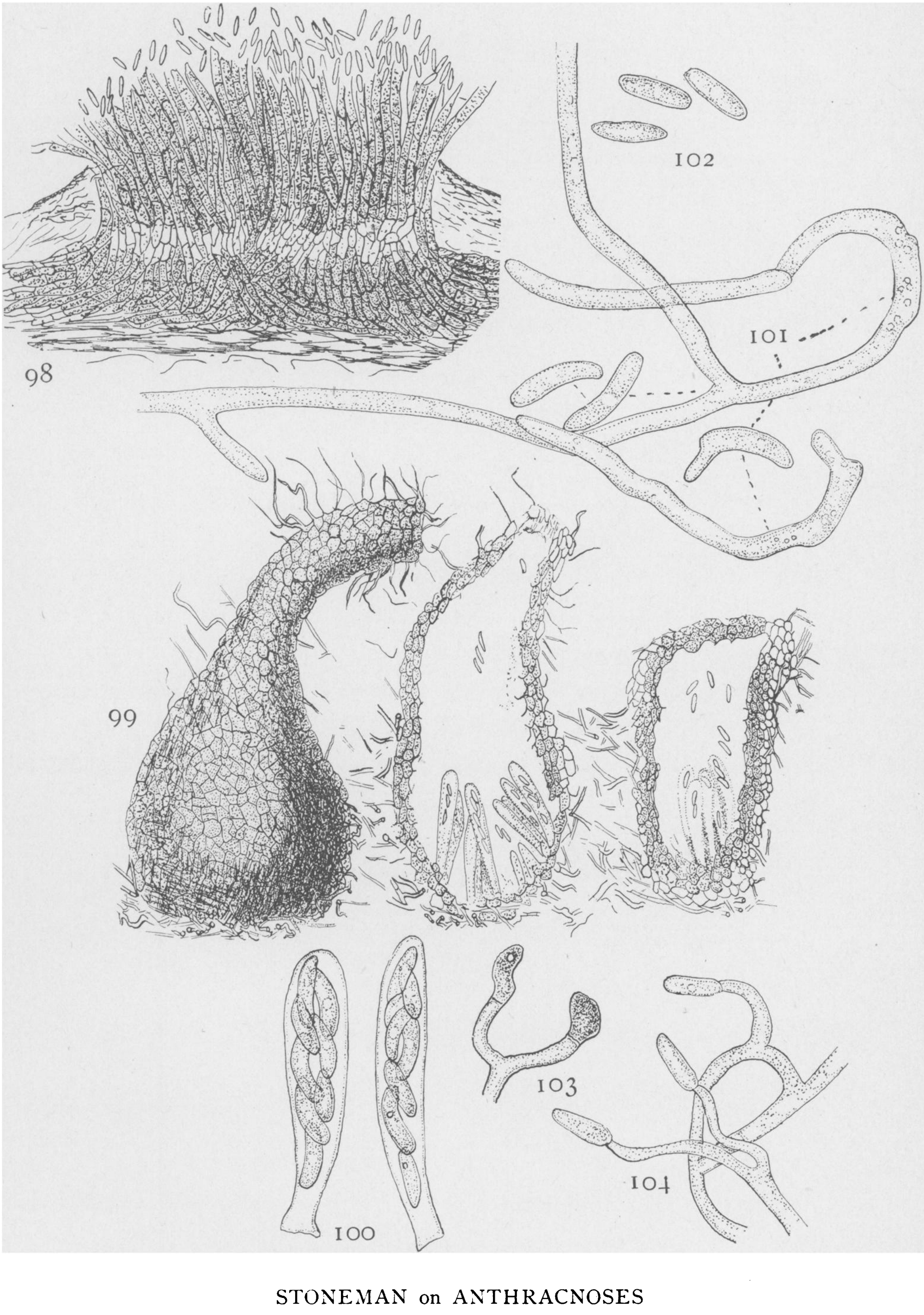

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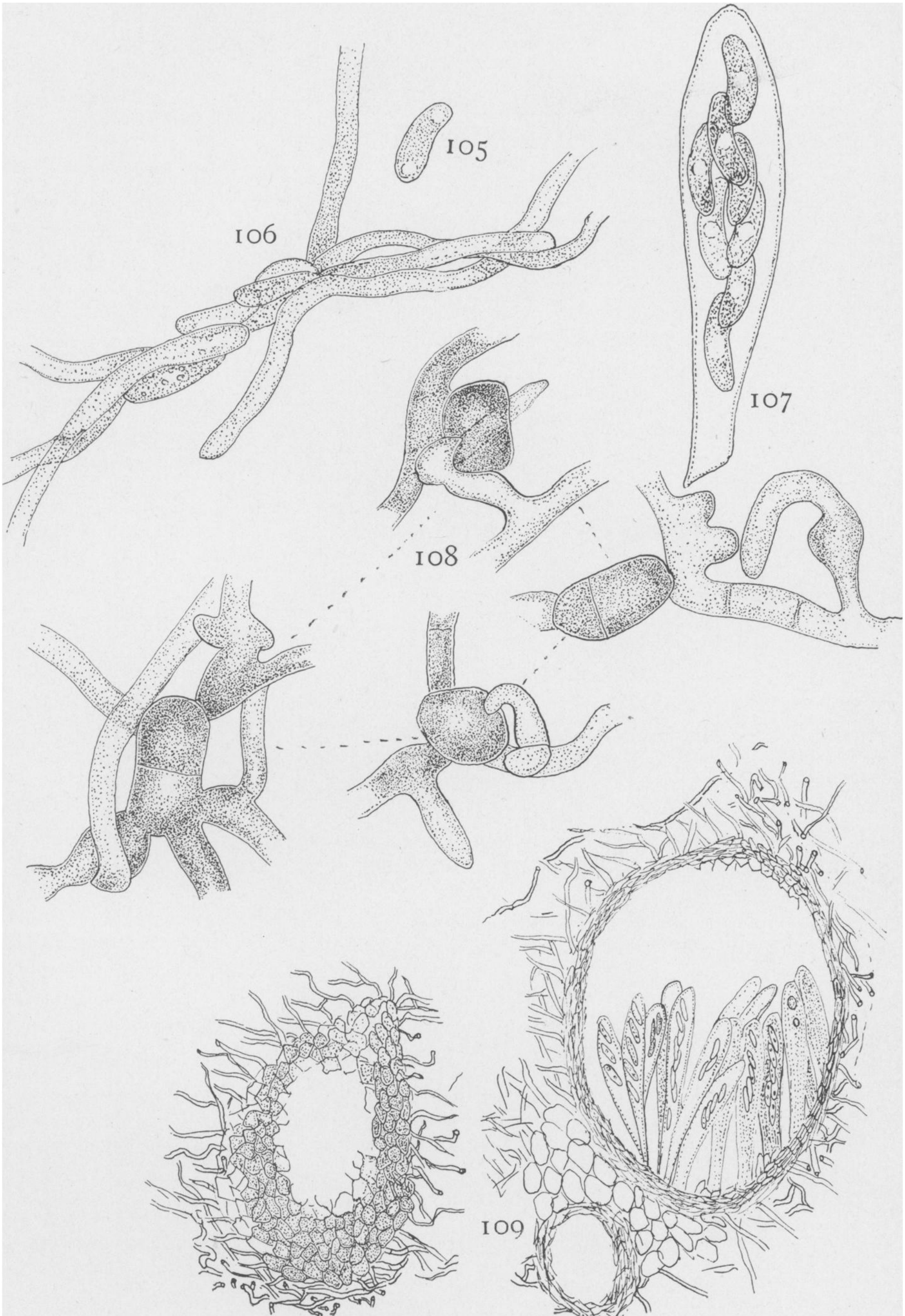

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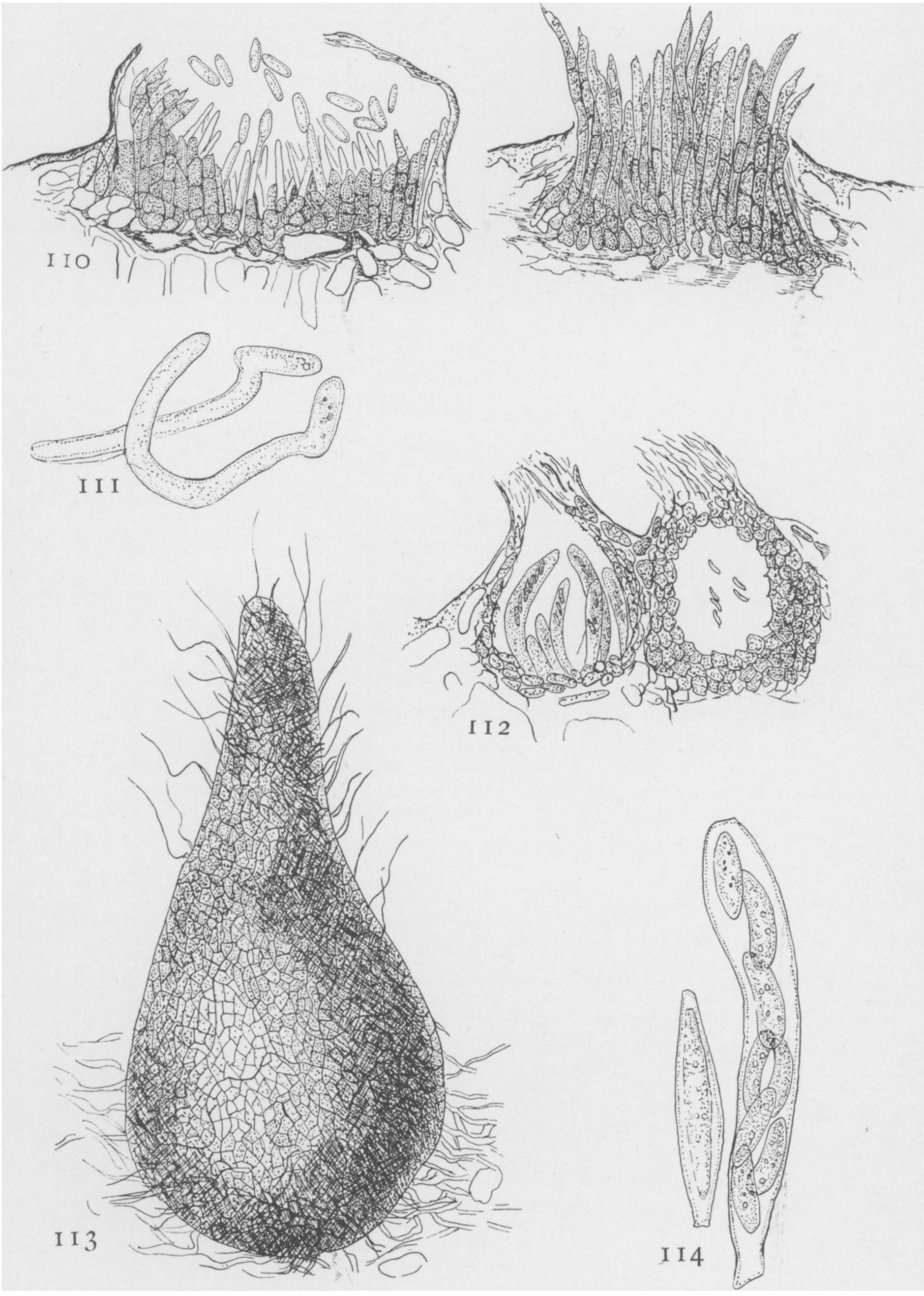

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